NICKEL MAGAZINE

THE MAGAZINE DEVOTED TO NICKEL AND ITS APPLICATIONS

NICKEL, VOL. 33, NO. 2, 2018

Nickel and sustainability: **Towards a circular economy**

Li-ion battery recycling What's in store for the future

High-temperature nickel alloys in concentrated solar power

Recovery of nickel from secondary materials

ACUAMED

CASE STUDY 13
ÁGUILAS FOOTBRIDGE

ACUAMED

The hand railing system on the bridge is austenitic stainless steel Type 316 (UNS S31600).

Pedestrians in the coastal resort town of Águilas in south-eastern Spain could not walk directly from the centre of town to the marina. The obstacle? A wide ravine known as the Rambla del Cañarete that carries large volumes of water at certain times of the year.

The challenge: The Águilas bridge project was initiated by Acuamed. It was looking for a durable, light yet strong solution, that was aesthetically pleasing and could weather the seaside air.

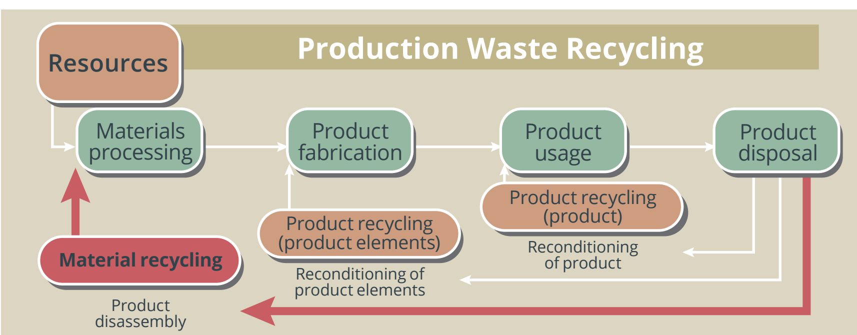
Material selection: Duplex stainless steel grade Type 2205 (UNS S32205) was selected because of its superior resistance to corrosion, low maintenance costs and attractive appearance. Its higher initial cost compared to conventional carbon steel was outweighed by the longer life span and lower repair costs. It was also very suitable for load-bearing members in bridges, satisfying the requirement for a light-weight, uncluttered structure.

Design: The structure consists of three main longitudinal girders. Twelve large rectangular holes are cut out of the web over the central two-thirds of the span to reduce wind-induced stress on the structure. The central girder is a fabricated hollow box beam connected by cross beams. The composite deck of the footbridge, consisting of a reinforced concrete slab and galvanised steel decking, is supported on the cross beams. Shear connectors connect the composite deck to the central longitudinal box beam and the cross beams, which stabilises the upper flange of the box beam as well as creating a rigid diaphragm for resistance to seismic actions. Ni

Download the full case study from www.nickelinstitute.org

EDITORIAL:
GOING IN CIRCLES

If you hear "we're just going in circles" your meeting is probably not making any progress. For metals such as nickel, however, it means you are right on track. That ideal circle looks like this:



A recent report[1] concludes that making better use of the materials that already exist in the economy could take EU industry halfway towards net-zero emissions. The reality is that, all along the way, there are losses: material that is not collected and losses because of inefficiencies and economic limits in recycling processes.

Research by Yale University shows that 17% of end-of-life nickel currently ends up in landfills. In this edition of *Nickel* we look at examples of how industry is responding to this challenge.

Progress in the recycling of nickel-containing batteries is increasing recovery rates (getting it back) and recycling efficiency (getting more back from what is recovered). The end-of-life recycling of automotive Li-ion batteries is becoming big business and several of the pioneers and their technologies feature in this issue.

As well as being an infinitely recyclable material, nickel is an enabler of other technologies which are contributing to sustainability. A great example is concentrated solar power where nickel alloys are essential to withstand high temperatures. Crescent Dunes is a stunning example as our cover attests. And the city of Houston has a beautiful new nickel-containing sculpture. Happily, it will be a long time – if ever – before Anish Kapoor's Cloud Column is recycled.

Clare Richardson
Editor, Nickel Magazine

[1] *Material Economics – The Circular Economy – A powerful force for climate mitigation – Transformative innovation for prosperous and low-carbon industry*

SOLARRESERVE

A modern lighthouse: the Crescent Dunes concentrated solar plant, Tonopah, Nevada. USA. An outstanding example of nickel enabling technologies that support sustainability.

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NICKEL NOTABLES

A sea of information

The Nickel Institute and the Copper Development Association, working in collaboration, have developed a new series of technical presentations. The series is aimed at engineers involved in the design, specification, fabrication or operation of materials in contact with seawater, in industries such as wave and tidal energy, offshore wind energy, offshore oil and gas, and shipbuilding and ship repair. Delivered by technical experts, the presentations help users better understand the behaviour of copper-based alloys, stainless steels and nickel alloys in marine environments. The presentations are available on the Copper Development Association website.

Why fret about guitar strings?

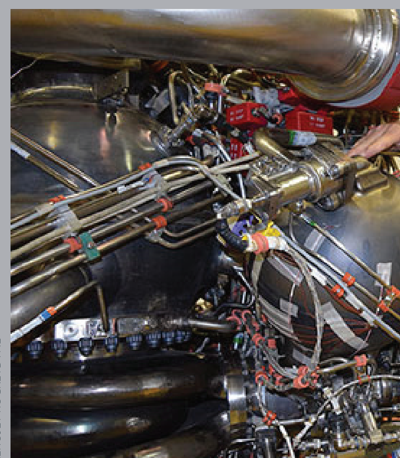
As the electric guitar became a key instrument in the evolution of pop music, pure-nickel strings were the standard in the 1950's and 60's.

In recent years, nickel-plated strings have become increasingly popular, sparking a debate about which is better. Some guitar purists crave that vintage smooth, warm tone, while others are satisfied with the brighter livelier sounds that nickel-plated delivers.

Pure nickel strings may cost a bit more but they generally last longer. Whatever the choice, nickel has been a longtime player in the music industry.

We have lift-off!

Nickel has played a small role in NASA's first launch of a rocket engine with a 3D-printed part. After several years of research and development, it was discovered that the copper alloy part could tolerate the massive pressure in the engine's combustion chamber when it had a nickel alloy jacket.



AEROJET ROCKETDYNE

Tiny temperatures

Scientists from the Tokyo Institute of Technology have developed a micrometre-wide thermometer consisting of a gold and nickel thermocouple on a silicon nitride membrane. It's able to measure the smallest temperature changes in real time. The device is a breakthrough for many important applications within nano-technology.

TESLA

Going that electric mile for less

In an effort to significantly reduce costs, Tesla has announced they are increasing the nickel content used in their EV batteries. Tesla has been able to make this change while retaining the highest energy density used in any electric car battery.

ACCELERATING LI-ION BATTERY RECOVERY AND MATERIAL RE-USE: **RECYCLING HIGH-VOLTAGE BATTERIES BECOMING BIG BUSINESS**

Fueled by the growing use in the automotive industry, the Li-ion global battery industry is expanding rapidly. With automotive battery life currently warrantied anywhere from five to eight years, end-of-life recycling will be big business in the not-too-distant future.

With nickel-containing Li-ion battery usage forecast to grow exponentially around the world in the next 20 years, end-of-life collection and recycling is poised to grow as well.

Proven recycling technologies and processes are already in place and can be expanded as needed. Around the globe, innovative companies are continuing to explore effective and economically viable methods to meet a future surge, driven by regulatory requirements on end-of-life responsibilities as well as the safe handling and transport of Li-ion batteries.

This will be supported by the positive economic value recovered from the materials, especially nickel.

The big difference: Automotive and energy storage

In China, where millions of electric vehicles are already in use, new legislation has put the responsibility of end-of-life battery collection and recycling on the car manufacturers who are now preparing for similar legislation in the rest of the world.

Very different from batteries in portable electronics, high voltage automotive batteries are large battery packs, consisting of 5,000-12,000 cells.

Improved Electrical Energy Storage involving nickel-containing batteries is increasingly key to providing electrical grid stability, improving the efficiency and reliability of wind and solar energy sources. Those large batteries will also require end-of-life management involving re-use or recycling.

Economic, environmental drivers

The industry needs closed-loop, energy-efficient and sustainable resource recovery processes and systems, coupled with a financial value proposition. The key economic driver for Li-ion battery recycling is the recovery of the valuable metals and their compounds found in the cathodes and anodes: cobalt, nickel, manganese, copper, lithium, which can be used for new battery formulations.

The volume of batteries becoming available for recycling in the medium term will justify new recycling facilities and investment in technological research that will increase material recovery and reduce costs.

Efficient Li-ion battery recycling is important for environmental reasons because of toxicity and safety. Proper handling and transportation are essential.

Emerging demand for innovation

The battery recycling process, which might be better described as the battery resource recovery process, can be pyro-metallurgical or hydro-metallurgical, or a combination of both.

Umicore

Belgium-based Umicore Battery Recycling combines pyro and hydro technology. This unique technology is operational at industrial scale (7000 t/year) and designed to safely treat large volumes of different types of complex metal-rich waste streams.

Battery packs are dismantled to the level of modules. These modules are directly fed into the process which avoids the need for any potentially hazardous pre-treatment. A gas cleaning system guarantees that all organic compounds are fully decomposed and that no harmful or volatile organic compounds are produced. The process reduces the consumption of energy and CO_2 emissions to a minimum by using the energy present inside the battery components (electrolyte, plastics and metals).

The subsequent hydro refining process recovers and purifies nickel, cobalt, copper and lithium. These cobalt, nickel and lithium units can then be used again in Umicore's Li-ion cathode materials, closing the battery loop. Precious metals from the battery management system are recovered in a separate process.

Glencore

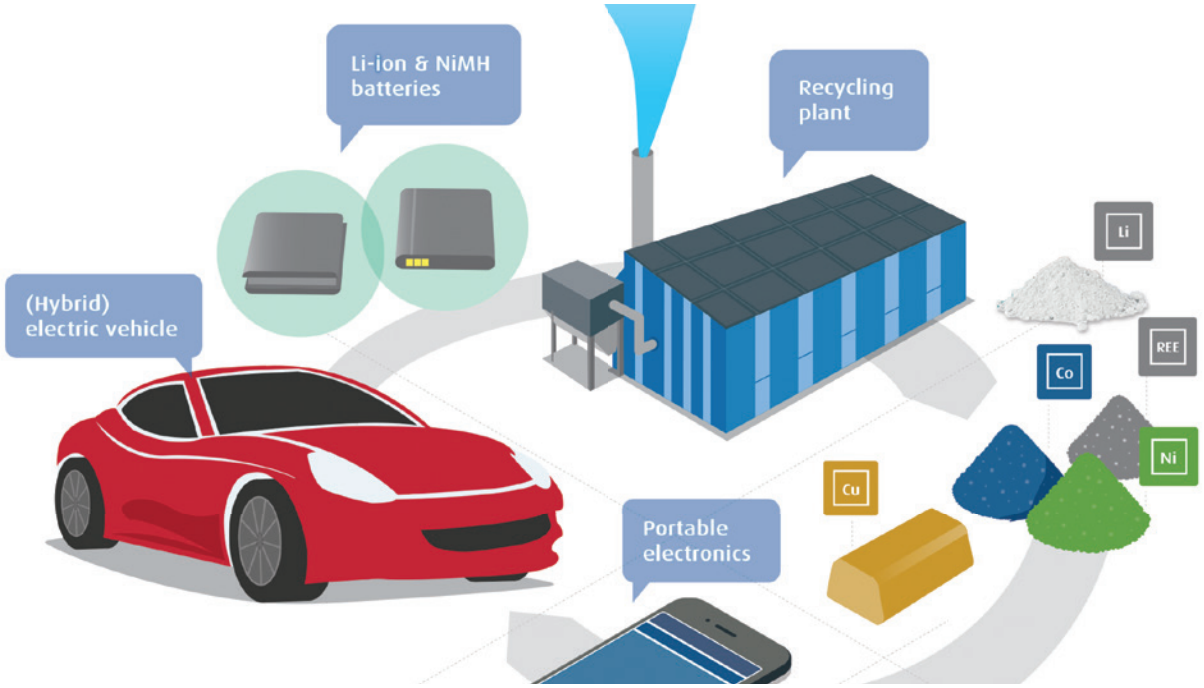
Glencore, a leading producer and marketer of nickel, is one of the largest recyclers and processors of nickel-bearing materials, including batteries.

Using a pyro-metallurgical process at its nickel smelting facility in Sudbury, Ontario, Canada, Glencore recovers nickel, cobalt and copper metals from NiMH and Li-ion batteries.

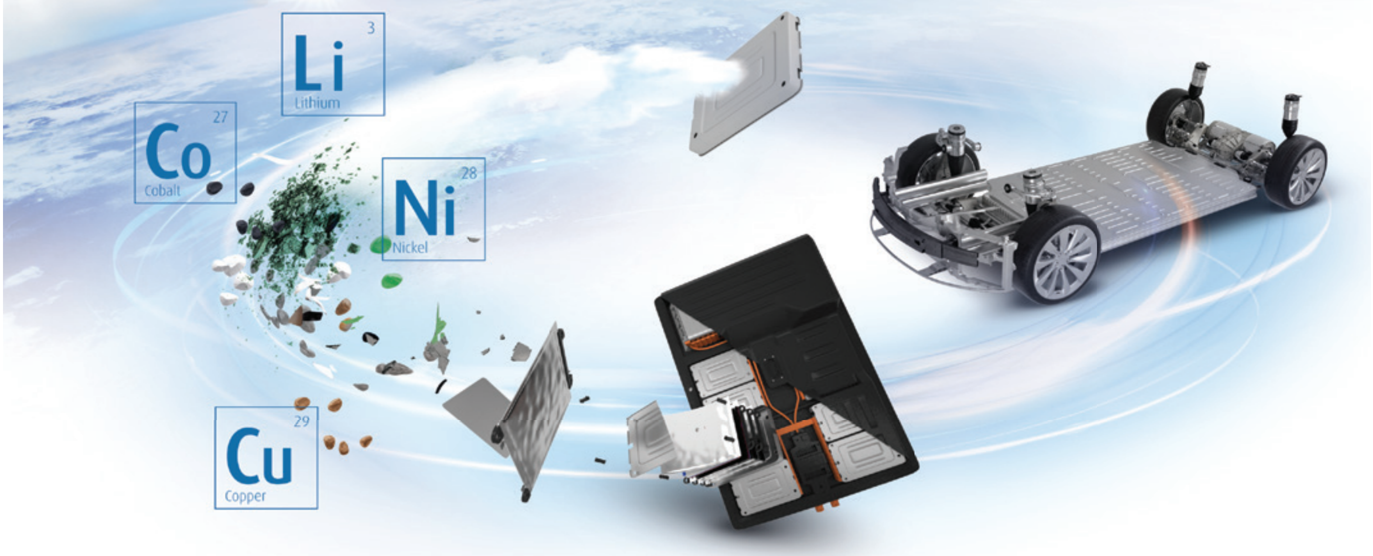
Through continuous efforts to improve its electric furnace and its converter technology, Glencore achieves very high metal recovery rates. The company has invested in a calciner (a long rotary kiln) where organic battery components are removed and safely renders the batteries inert. It is a "green" technology and all of the calciner gases are captured and safely managed.

"With our expanding battery recycling, we maximise safety by pre-treatment of the battery cells at various facilities

In a recent forecast, Bloomberg New Energy Finance projects annual electric vehicle sales to reach 41 million units by 2040. Avicenne Energy forecasts show annual growth of 14-17% in automotive applications. Demand for portable consumer electronics, e-bikes, lawn mowers and many other applications for Li-ion batteries is also expected to continue to grow 5-12% per year in the future, according to Avicenne.



UMICORE BATTERY RECYCLING



Anticipating strong demand, Bloomberg New Finance projects Li-ion battery production capacities to more than double over the next five years reaching 273 GWh in 2021, compared to 103 GWh in 2017.

globally," says Robert Sutherland, Raw Material Manager at Glencore.

Li-Cycle Corp.
Canadian company, Li-Cycle Corp., based in Mississauga, Ontario, has developed a proprietary process to address the emerging international demand.

Li-Cycle Technology™ is a two-step hydro-metallurgical resource recovery process. The first step is an automated process that dismantles the battery cells/packs, without risk of combustion or explosion. The second step consists of chemically treating the mechanically processed intermediate product to recover the nickel, cobalt, copper, aluminum and lithium in the form of battery chemicals. In the case of nickel, nickel sulphate can be directly used by the battery industry.

This closed-loop process recovers all battery materials, including plastics, electrolytes and graphite. There are no primary gases to capture and no solid waste to manage. All materials go back to the economy in some form.

"We believe 5-10% of nickel sulphate demand could be met through the recycling of Li-ion batteries by 2025," says Ajay Kochhar, Li-Cycle Corp. CEO.

American Manganese Inc.
In Vancouver, British Columbia, Canada, American Manganese Inc. and its third-party contractor, Kemetco Research Inc., have developed an energy-efficient, environmentally friendly hydro-metallurgical battery recycling process.

Li-ion batteries are ground into a powder by Kemetco and plastics burned off. The powder is then subjected to leach extraction of the metals. The result is high purity lithium, cobalt, nickel, aluminium and manganese powder, suitable for direct recycling back into new Li-ion batteries. At bench scale, Kemetco reports 100% recovery rates with this process. Large scale processing recovery rates are expected to be slightly lower.

"Our strategy is to set up small plants at several different locations within proximity of markets", says Larry Reaugh, American Manganese Inc. President and CEO.

When the stream of end-of-life nickel-containing batteries becomes a torrent, forward-thinking companies are ensuring the recycling technology and capacity will be there. Ni

INCREASING RECOVERY OF NICKEL FROM SECONDARY MATERIALS

The increasing use of nickel in many important technological applications has resulted in sustained growth in its demand over many decades. With a historic growth rate of around 4% per year, the annual demand for nickel in recent years has doubled over the working life of a typical mine (20 years), meaning there would need to be two new mines opened for every one that closes.

Not surprisingly, this has sparked a drive to increase recycling rates to complement primary production. For example in the USA, nickel from recycling now amounts to 45% of primary supply, up from 35% in 1994. With primary supply growing, reclaiming nickel through recycling must also grow, just to keep up.

Need for more "urban mining"

Clearly, new secondary sources are required to meet society's increasing need for nickel.

In some cases, society's wastes contain higher valuable metal content than naturally-occurring ores.

Petrochemical industry promising

The petrochemical industry has some of the most promising secondary sources of nickel.

Crude oil naturally contains low levels of nickel, which becomes concentrated in the ash fraction and comprises typically around 10 wt% in fully combusted ash from heavy fuel oil combustion systems. Catalysts used in refineries and the petrochemical industry contain very high amounts of nickel. Previously they were often sent to landfills, but more and more are being recycled. *(See story page 15.)*

Steel production has high potential

Since over two-thirds of all nickel is used in the production of stainless steel, the ferro-alloy output of most smelting-based recovery methods makes them an obvious source of secondary nickel.

Tetronics' DC plasma arc smelting is one typical example, with two commercial plants operating for decades to recover nickel, chromium, molybdenum and other metals from stainless steel production wastes.

"Coke or anthracite reductant is added to the feed material. The plasma arc provides the input energy to produce a ferroalloy for re-use in stainless steel production at a scale ideally suited to the current availability of spent petrochemical catalysts and related secondary materials," explains Dr. Tim Johnson, Tetronics' Technical Director. Ni

TETRONICS

"Low gas flows in the furnace and close control of smelting conditions ensure minimum generation of off-gas dusts and excellent environmental credentials. With the relentless pressure for increased metal supply, it seems certain we will see an expansion of dedicated processing capacity for these and other secondary sources of nickel at Tetronics over the next few years."

— Dr. Tim Johnson
Technical Director, Tetronics

THE AMAZING ROLE OF **HIGH-TEMPERATURE NICKEL ALLOYS AND STAINLESS STEELS** FOR CONCENTRATED SOLAR POWER

SOLARRESERVE

As of 2016 there was a total installed CSP capacity of 4,815 MW globally. In 2017, Spain operated almost half of the world's capacity with 2,300 MW. The USA has 1,740 MW installed, with two of the largest projects in the world: Ivanpah Solar Power Facility (392 MW), and the Mojave Solar Project (354 MW).

Nickel-based alloys and nickel-containing stainless are playing key roles in an emerging source of renewable energy known as thermal solar plants or concentrated solar power (CSP). Their use has enabled the industry to overcome challenges in heat transfer and thermal storage technology. The use of these materials serves to prevent degradation or replacement costs for projects with design lives of up to 40 years or longer.

According to the International Energy Agency (IEO 2017), consumption of energy from renewable energy sources (including CSP) will grow at 2.3% annually between 2015 and 2040. Today, there are currently more than 40 solar thermal power plants operating around the world, with another 20 either in the planning stage or under construction. They tend to be located in areas with high solar irradiance such as Spain, India, South Africa, China, Chile, Australia, Middle East North Africa region (MENA) and the southern United States.

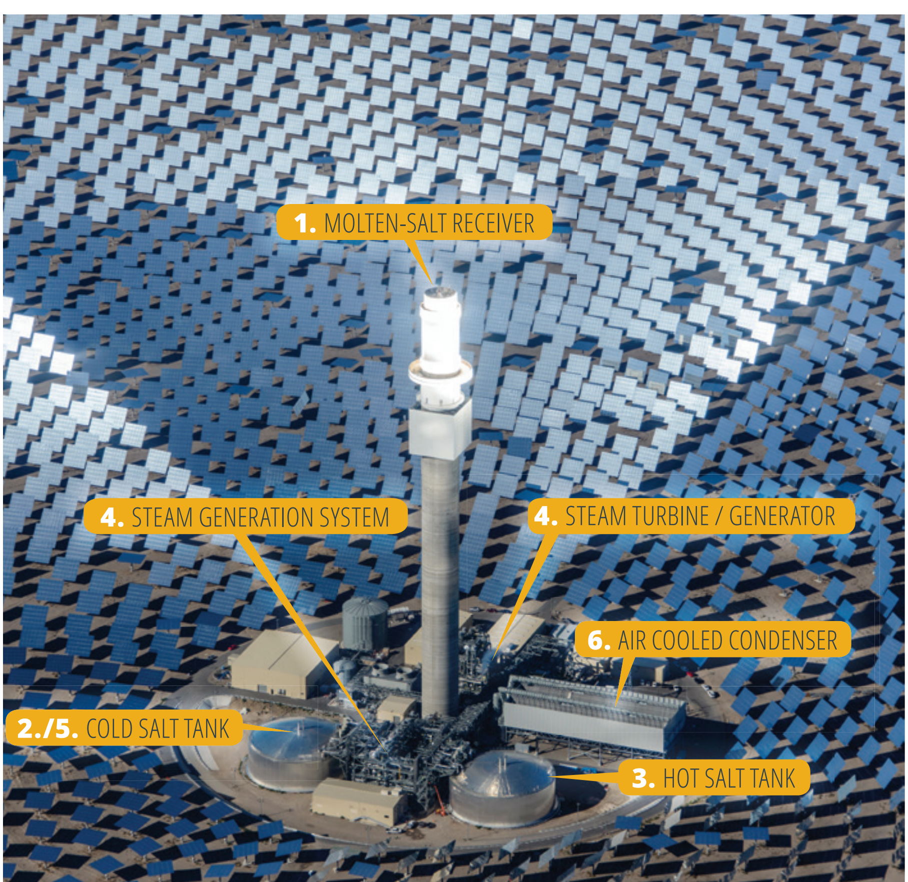
Demonstration CSP plants began operating as early as the 1980s. Since then, advances have been made in both collection and energy storage. The solar tower is one concentration technique that has been developed. The design utilises molten-salt as a heat transfer fluid. Mixtures of nitrate salts typically melt at or above 130 °C (268 °F). They are maintained as liquids at temperatures of 288 °C (550 °F) in an insulated storage tank. The liquid salts are then pumped through tubes in a solar receiver where the concentrated radiation heats them to temperatures up to 566 °C (1,050 °F). The hot liquid is then sent to a high-temperature storage tank. The hot tanks are also insulated and can store thermal energy for extended periods. Thermal Energy Storage (TES) is used to compensate for varying demand and ambient conditions. When required, molten-salt is pumped to a steam-generator to produce steam for driving conventional turbines and generators. TES represents a distinctive advantage over other large utility-scale, renewable energy sources and can in some circumstances eliminate the need for backup fuel for power generation. During the summer of 2013, a molten-salt tower system in Spain continuously produced electricity 24 hours per day for 36 days – a first-time achievement.

One operating plant of this type is Crescent Dunes. Located at Tonopah, Nevada in the desert north of Las Vegas, it has a net electrical generating capacity of 110 MW and ten hours of TES. This means that the plant is able to generate power under full load for up to ten hours during peak demand. The sun is reflected from over 10,000 heliostats that focus energy to the receiver located at the top of a 200 m (640 ft) tower. Each heliostat is made up of mirrored facets which add up to an area of 115.7 m^2 (1,245 ft^2). The total collection area is over 1.2 million m^2 (12 million ft^2). Commercial start-up began in 2015. Since that time Crescent Dunes has produced over 173 GWh of electricity, and it is estimated to provide peak power for 75,000 homes. CSP with solar tower(s) and molten-salt is the design basis for new planned projects in South Africa, Australia and Nevada. The 100 MW South African Redstone project will provide peak power to approximately 200,000 homes, and have a TES of 12 hours. A new, larger scale Nevada project will have a capacity of 2 GW (2,000 MW) with 10 solar towers.

The use of stainless steel and nickel alloys has made higher temperature systems viable, where handling molten-salts was previously a challenge. Designers and engineers have turned to nickel-based alloys such as UNS N06617, N06625 and N06230 for receiver tube applications due to their high-temperature strength sustained over long periods – known as creep resistance. These alloys remain stable at the operating temperatures primarily due to their high nickel content, and have high oxidation resistance as well. Stainless steel Type 347H (S34709) is used for the high-temperature storage tanks. Ni

SOLARRESERVE

Crescent Dunes, is located at Tonopah, Nevada in the desert north of Las Vegas. It has a net electrical generating capacity of 110 MW and ten hours of TES. This means that the plant is able to generate power under full load for up to ten hours during peak demand.



SOLARRESERVE

Solar Tower Concentration Technique

1. *Sunlight is concentrated and directed from a large field of heliostats to a receiver on a 195 m (640 ft) tower*
2. *Liquid salt from the cold salt tank is pumped through the receiver where it is heated to 566 °C (1050 °F)*
3. *The heated salt from the receiver is stored in the hot salt tank*
4. *Hot salt is pumped from the hot salt tank through a steam generator to create steam, which drives a steam turbine, generating electricity*
5. *Cold salt at 288 °C (550 °F) flows back to the cold salt tank*
6. *Condensed steam from the steam turbine is recirculated for reuse*

NICKEL RECYCLING: TOWARDS A CIRCULAR ECONOMY

Recycling is a key pillar in global initiatives striving towards a more sustainable society. As outlined by the United Nation's Sustainable Development Goals: 17 goals to transform our world, *"responsible consumption and production" is at the core of a circular economy and plays a critical role in mitigating climate change.*

When it comes to recycling, what sets metals like nickel apart from other raw materials?

Infinite opportunity

First of all, nickel can be infinitely recycled without loss of quality. Generally, metals from primary raw materials cannot be distinguished from recycled metals. As a result, special emphasis is put on ensuring that as much nickel as possible is collected and recycled at its end-of-life.

Secondly, with its 68% recycling rate, nickel is amongst the metals with the highest recycling efficiencies. This means that more than two-thirds of all nickel in consumer products is recycled once these products reach their end-of-life. The recycled nickel enters a new life-cycle, much of it as stainless steel and around 15% in the carbon steel loop.

The recycled nickel enters a new life-cycle, much of it as stainless steel and around 15% in the carbon steel loop.

Yet data analysis shows that 17% of nickel is still not recycled.

Room for further efficiency

Research has played a key role in measuring and assessing recycling rates. The goal is to capitalise on future opportunities to further reduce the amount of nickel ending up in landfill.

The UNEP International Resource Panel, launched in 2007 to build and share the knowledge needed to improve our use of resources worldwide, published a report on the recycling of metals in 2011.

Under the lead of Professor Thomas Graedel from Yale University, a team of experts from academia, industry and civil society examined the recycling of more than 50 metals. The report assessed recycling efficiencies for base metals, precious metals and minor metals. The work shows where the greatest needs are to improve recycling.

Professor Graedel's team notes, "There are significant differences in recycling efficiencies of the metals assessed: on the one hand, base metals such as carbon steel have high recycling efficiencies, while rare earth elements are currently hardly recycled. Different factors play a role, such as use patterns, whether there is an economic incentive to collect, or if there is an available collection and recycling infrastructure."

Ongoing research

Nickel and stainless steel are amongst the best investigated raw materials in view of stock (amount of nickel currently in use in society) and flow modeling and recycling. One of the researchers involved in drafting the UNEP report was Dr. Barbara Reck, a senior researcher in Professor Graedel's team at Yale University. With support from Team Stainless and the Nickel Institute, she has spent several years investigating the flows and stocks of nickel and stainless steel. Her work has been published in several peer-reviewed journals. The models were compiled for the reference years 2000, 2005 and 2010. Currently, Dr. Reck is finalising an update of the nickel stocks and flow models.

"The work will show the stocks and flow models and recycling rates for 2015," explains Dr. Mark Mistry, the Nickel Institute's expert on life-cycle analysis for nickel. "Trends which can be seen between the first investigation in 2000 and 2015 show the increased relevance of Asia in nickel supply and use, the fast-growing stocks of nickel in society and also indicate a trend in improved recycling of nickel."

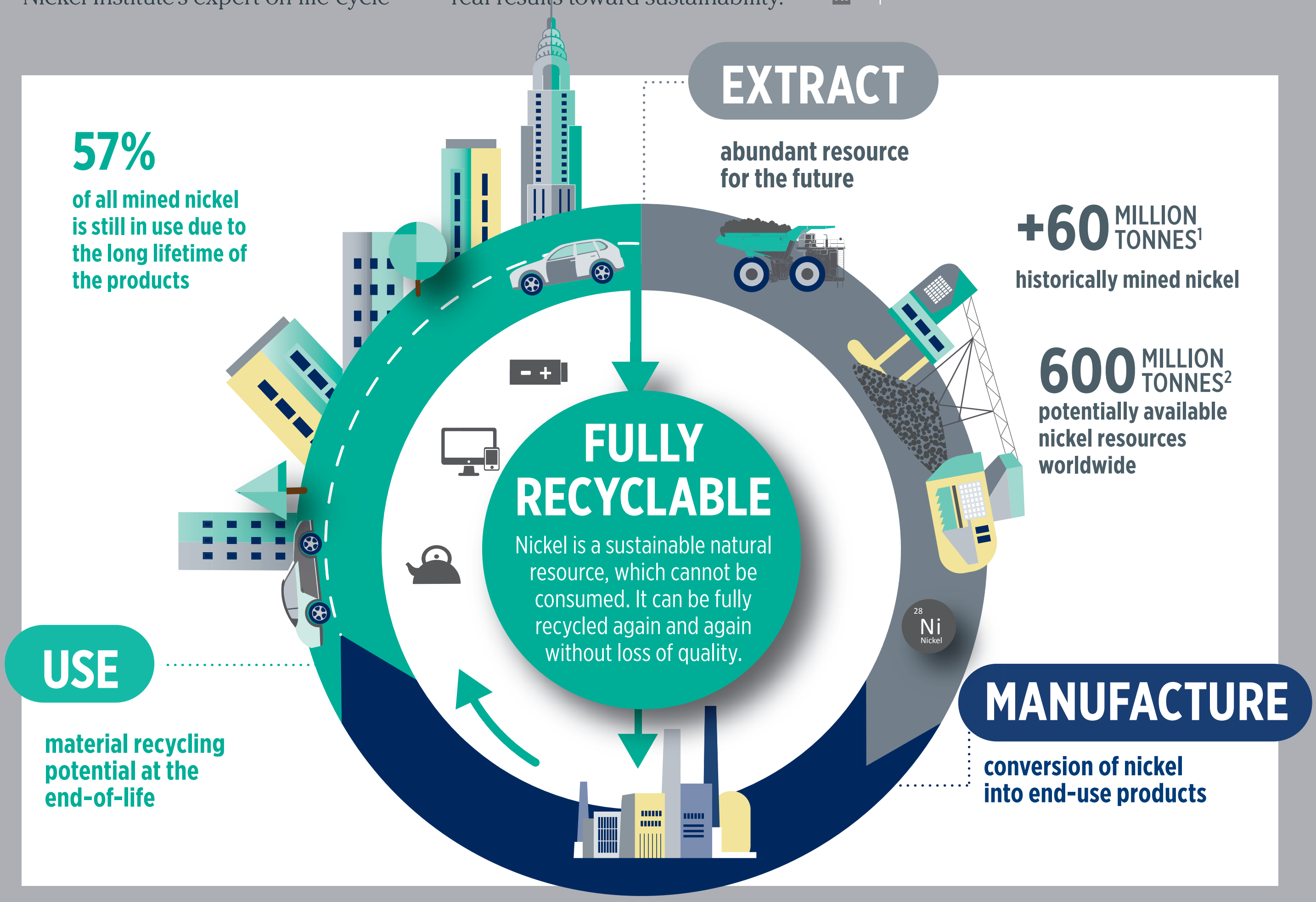
Similar work done for stainless steel confirms these trends for the major first use of nickel. The work is expected to be published late 2018/early 2019.

Industry plays role

There is also a role for industry to play. The amount of nickel going inadvertently into the carbon steel loop shows potential to be further reduced. For example, improved sorting systems are critical to ensuring that more nickel-containing goods such as stainless steel are separated from carbon steel scrap.

The good news is, working together to increase nickel recycling and reduce waste is a tangible goal that is creating real results toward sustainability. Ni

Recycling nickel is an important factor in nickel life-cycle and an important contributor to global sustainability. Products containing nickel, such as stainless steel, are durable and are in use for a long time. The demand for nickel is growing. Nickel recycling is part of the solution, as a complement to primary production.



1. USGS Minerals information: Historical Global Statistics for Mineral and Material Commodities.
2. Mudd and Jowitt (2014) – A detailed assessment of global nickel resource trends and endowments. Economic Geology v. 109 pp 1813-1841.

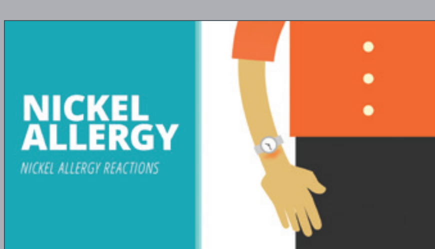
Nickel Institute leadership change

Dr. Hudson Bates has been appointed President, Nickel Institute, effective 1 June 2018 to succeed David Butler, whose mandate was completed on 31 May. Hudson Bates moves into the role having led the Nickel Institute's science activities as Executive Director, NiPERA Inc. For the last 20 years, Dr. Bates has applied his specialised knowledge to the study of the toxicology of nickel and its compounds. Commenting on this appointment, Anton Berlin, Chairman, Nickel Institute, said, "With his exemplary record of accomplishments, Hudson is ideally positioned to lead the Nickel Institute and the nickel industry in promoting and supporting the use of nickel in appropriate applications." Ni

Dr. Adriana Oller appointed Executive Director of NiPERA

Dr. Adriana R. Oller has been appointed Executive Director of NiPERA, Inc., the science division of the Nickel Institute, succeeding Dr. Hudson Bates. In her new role she is responsible for the strategic research direction of NiPERA as well as guiding the research, regulatory and communication activities of six doctoral level scientific staff. Adriana Oller brings over 24 years' experience as a human health toxicologist, during which time she has maintained a high level of scientific interaction, guiding research programs and addressing regulatory issues. She has co-authored many peer-reviewed papers on nickel toxicology. Dr. Oller is recognised by her peers as a leading expert in human health effects of nickel. Ni

NEW VIDEOS

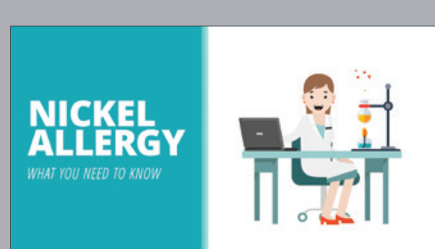


https://www.youtube.com/user/NickelInstitute

Nickel allergy explained

The Nickel Institute has produced a new series of videos to provide information on nickel allergy. Dr. Kate Heim, NiPERA Inc.'s expert toxicologist on the subject, explains nickel allergy and how to avoid it.

Watch the videos on the Nickel Institute's YouTube channel. Ni



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A CATALYST FOR SUSTAINABLE OPERATIONS

Nickel-containing catalysts are widely used in the refining and petrochemical industries worldwide. At end-of-life, catalysts are either sent to landfill or sent for recycling to recover the valuable metals they contain. Refineries in Kuwait are changing the way they handle spent catalysts.

A catalyst is a substance which speeds up chemical reactions or causes the reaction to take place under conditions it would not normally occur. The catalyst material generally has a very high surface-to-weight ratio, and is sometimes attached to an inert material such as alumina or silica. Many nickel catalysts are so reactive they will auto-ignite, that is, catch fire when exposed to air. The nickel content is often proprietary but can range from as low as 1.5% to as much as 98% of the total catalyst weight.

In oil refineries, nickel catalysts play a key role in several processes – hydrotreating, hydrocracking and steam reforming. In those first two processes, nickel acts as a promoter, that is, it increases the efficiency of the process. Steam reforming is a high temperature process which breaks down a fuel such as natural gas into hydrogen, carbon monoxide or other useful products. Here nickel is the main catalyst metal.

After a period of use, the catalyst becomes "spent" and no longer efficient. It is estimated that refineries worldwide generate roughly 150,000 tonnes/year of spent catalysts of all metals. Kuwaiti refineries alone generate about 6,000-7,000 tonnes/year. In the past most of this was sent to special landfills as hazardous waste, as there were no sites in the Middle East for recycling of such materials. Increasingly, the Kuwaiti refineries have become aware that this is not a sound environmental solution. Specialised metal recyclers are willing to take the spent catalysts and send them to a proper recycling centre where the valuable metals can be recovered. Dr. Ashish Pathak of the Kuwait Institute for Scientific Research (KISR) clarifies that "Due to the environmental concerns and company sustainability policies, the preferred option these days in Kuwaiti refineries seems to sell the spent catalyst to metal recyclers." Ni

Specialised metal recyclers are willing to take the spent catalysts and send them to a proper recycling centre where the valuable metals can be recovered.

UNS DETAILS

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

UNS	Al	B	C	Co	Cr	Cu	Fe	La	Mn	Mo	N	Nb	Ni	P	S	Si	Ti	W
N06230 p. 11	0.20-0.50	0.015 max	0.05-0.15	5.0 max	20.0-24.0	–	3.0 max	0.005-0.050	0.30-1.00	1.0-3.0	–	–	bal	0.030 max	0.015 max	0.25-0.75	–	13.0-15.0
N06617 p. 11	0.8-1.5	0.006 max	0.05-0.15	10.0-15.0	20.0-24.0	0.5 max	3.0 max	–	1.0 max	8.0-10.0	–	–	44.5 min	–	0.015 max	1.0 max	0.6 max	–
N06625 p. 11	0.40 max		0.10 max	–	20.0-23.0	–	5.0 max	–	0.50 max	8.0-10.0	–	3.15-4.15	58.0 min	0.015 max	0.015 max	0.50 max	0.40 max	–
S31600 p. 5	–	–	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	0.75 max	–	–
S34709 p. 11	–	–	0.04-0.10	–	17.0-19.0	–	bal	–	2.00 max	–	–	8xC min 1.00 max	9.0-13.0	0.045 max	0.030 max	0.75 max	–	–

CLOUD COLUMN A MONUMENTAL NICKEL-CONTAINING STAINLESS STEEL SCULPTURE AT THE MUSEUM OF FINE ARTS IN HOUSTON, TEXAS

Cloud Column is another artistic masterpiece by British-Indian artist Anish Kapoor, renowned for creating the stainless steel Cloud Gate sculpture that defines Millennium Park in Chicago.

Conceived in the late 1990s and realised in 2006, Cloud Column was originally commissioned for the British Museum. It was later acquired by Houston's Museum of Fine Arts as one of two public sculptures to be featured on the museum's redeveloped campus.

The 8.95 x 3.32 x 2.03 metre oblong-shaped sculpture is fabricated from Type 316 (UNS S31600) stainless steel and weighs just under ten tonnes. It is hand-made from stainless steel plates, welded together in segments and formed into shape. The unique, hand-crafted execution of the sculpture resulted in a subtle, wave-like surface, creating multiple reflections.

One side of the sculpture is convex, while the other side is concave. When viewers look into the sculpture's concave front, their reflection and surroundings are flipped upside down, inviting them to contemplate not just the object itself, but how we position ourselves in relation to the world around us.

The installation took two days and a massive crane to raise the sculpture 50 metres over the Glassell School of Art and onto its base in the Brown Foundation, Inc. Plaza. It was hand-polished during and following installation to achieve a true mirror finish.

Cloud Column is an inspiring addition to the Museum's revitalised campus. Unveiled in May 2018, the sculpture is already a landmark attraction in Houston and will continue to awe its spectators for decades to come thanks to the durability and reflective appeal of stainless steel. Ni

Anish Kapoor, Cloud Column, 1998–2006, stainless steel, the Museum of Fine Arts, Houston, Museum purchase funded by the Caroline Wiess Law Accessions Endowment Fund.