NICKEL

THE MAGAZINE DEVOTED TO NICKEL AND ITS APPLICATIONS

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Chemical Regulation: Within REACH

EU Occupational Exposure Levels

Fuel Cells: A Work in Progress

Green Scrap: Making *New* Stainless Steel

Green Chemical: Nickel Hydroxide

Green Cars: Recycling Batteries

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PHOTO: ISTOCKPHOTO © TOR LINDQVIST

NICKEL

The Magazine Devoted to Nickel and its Applications

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A WORLD OF CHEMICALS

CHEMICALS ARE CENTRAL TO OUR LIVES. INDUSTRIES PROFIT FROM THEIR MANUFACTURE AND USE. CONSUMERS BENEFIT FROM PRODUCTS THAT CONTAIN MATERIALS DERIVED FROM CHEMICALS OR THAT CONTAIN THE CHEMICALS THEMSELVES.

Employees benefit from the wages dependant on their manufacture and use. The environment, too, can benefit if a safe chemical is substituted for one that is harmful.

At the same time, those who are exposed to chemicals, either occupationally or through consumer products, will want to know that those exposures are below thresholds that pose significant risk to themselves or the environments in which they live. There is sufficient history to justify this concern.

Finding the balance between costs of all kinds and benefits of all kinds is a continuing challenge. Meeting it requires understanding – and understanding in turn requires data and knowledge. That is why in this and future issues of *Nickel* you will find more attention paid to nickel chemicals (even though they represent less than 10% of nickel use). We will explain what they are, where they are used, how they are managed through their life cycles, and how they are regulated.

This new direction is on display in a new regular feature called *Knowing Nickel*. The first chemical featured here is nickel hydroxide $Ni(OH)_2$, a foundation chemical for many battery chemistries that are of increasing importance if the world is to have sustainable transportation. Elsewhere in this issue you will find a story on how hybrid and electric car batteries (which contain nickel hydroxide) are managed at end-of-life (page 14).

The regulation of chemicals is a growth industry in itself and the last decade has seen a move, led by the European Union (EU), to radically revise how that is done. The EU's Registration, Evaluation and Authorization of Chemicals (REACH) legislation is now in place and influencing how governments around the world are approaching chemicals management. On page 9 you will find an update on the progress being made on nickel chemicals in the context of REACH, as well as a status report on the review of Occupational Exposure Levels in the EU on page 11.

We will always, of course, bring you news of how nickel-containing materials are making a difference in architecture and engineering, and this issue continues that tradition. But it's a chemical world and *Nickel's* broadening scope will reflect that reality.

Stephanie Dunn
Editor, Nickel Magazine

'Mining' Stainless Steel

Exploring the Essential Role of Stainless Steel Scrap

Stainless steel is first a product; and, after a useful life, often measured in decades, it becomes a resource. This is true of all types of stainless steels but especially the nickel-containing grades which make up 55-60% of all stainless steel.

It is wrong to think of end-of-life stainless steel as "only" scrap. The best way to make new nickel-containing stainless steel product – product that is cost-effective, environmentally safe and energy-efficient – is to start with nickel-containing stainless steel. That means scrap stainless steel is the first and best "resource" for steelmakers.

The Value of Scrap

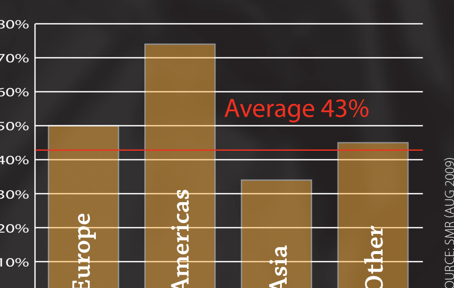
The desirability of scrap is reflected in its price: depending on economic conditions and geography, the price of nickel in stainless steel scrap can approach that of metallic nickel on the London Metal Exchange. At times in 2009, the discount between nickel in scrap and metallic nickel was less than 5%, and in the United States the discount disappeared completely: nickel in scrap held the same value as "virgin" nickel from nickel ore processed by a nickel refinery.

Without first manufacture, there can be no scrap. In the beginning, all stainless steel was made from virgin alloying elements. This was about a century ago, long before people started taking an interest in the recycled content of materials. Recently, however, the research firm SMR reported that the external scrap ratio rose to a worldwide average of 43% in 2008 (see graph). (The ratio considers only the scrap brought into the stainless steel plant and excludes any generated internally.) Moreover, one of the leading processors of stainless steel scrap, Cronimet of Karlsruhe, Germany, has grown to become the sixth-largest supplier of nickel in the world. The corporation supplies approximately 80,000 tonnes of nickel contained in scrap.

> "The best way to make new nickel-containing stainless steel product is to start with nickel containing stainless steel."

Location of Scrap

Like resources in nature, the scrap resource that accumulates in societies is not equally distributed. End-of-life products that contain stainless steel are found in greater concentrations in older, developed economies. There is relative scarcity in economies which do not have a history of high levels of stainless steel usage and are now



Selected Trade of Stainless Steel Scrap (all types) 2008*
1000s of metric tonnes

Origin	Destination		
	USA/Mexico/Canada	**Europe**	**Asia**
USA/Mexico/Canada	155	152	1117
Europe	1.5	1877	548
Asia	1.5	23	695

*Developed from statistics provided by the International Stainless Steel Forum (http://www.worldstainless.org); the numbers have been rounded.

producing stainless steel. The unequal distribution often leads to competition for available scrap, and there are significant flows of nickel-containing scrap between different parts of the world.

It follows that the price difference between nickel-in-scrap and primary nickel will be greatest in areas with modest growth and a long history of stainless steel use. Should the discount grow significantly, however, it will become ever more attractive to stainless steel producers in areas of limited scrap availability, and the flow of scrap to those areas will increase. The table above shows strong flows of stainless steel scrap to Asia, where both the use and production of stainless steels have rapidly increased.

Future of Scrap

Nickel-containing stainless steels are valued for their properties. Every issue of *Nickel* magazine provides examples of performance in terms of strength, enhanced corrosion resistance, durability, ductility, aesthetics – that are expected and achieved. Nickel-containing stainless steels are designed for a hard life and, more typically, a long one. The need for this material will only increase, and so will the demand for scrap.

Conservative estimates of the average service life of stainless steel range from 15 to 20 years, though some scrap will become available earlier (exhausted catalysts, batteries, and automobile scrap, for example), and some, much later. The stainless steel of the Chrysler Building in New York City, for example, has been in place for 80 years and there are no plans for its replacement. This implies that the need for "new" nickel-containing stainless steels will continue to grow even as the amount in use grows. The amount of nickel-containing stainless steel that becomes available as scrap will increase, meaning that the amount of "new" stainless steel coming from scrap will also increase.

Nickel from mines will always be needed. Nickel "mined" from the discards of society is vital today and can only grow in relative importance. Ni

Recycled Content

A measure of environmental acceptability?

In 2008, the average recycle content of stainless steels was 43%. Many were left wondering why it wasn't higher. The recycled content of new stainless steel products turns out to be a poor measure of their "green-ness". The paper industry, for example, is proud to claim that more than 63% of paper products are recycled at the end of their life. The remainder go to landfill or incineration. In contrast, almost all stainless steels are recycled – hardly any go to landfills.

While market demand for nickel and nickel alloys continues to expand, the available scrap is limited because stainless steels typically remain in service for many years. In other words, the 43% recycled content achieved in 2008 was as high as the supply of scrap permitted. The durability, corrosion resistance, toughness, and other good properties of stainless steels enable them to continue to serve for very long periods, but keep them unavailable for recycling. Because these materials will only gradually become available for recycling as the years and decades pass, the recycled content of stainless steels will remain an unhelpful measure of the real contributions they make to sustainability. Ni

OLYMPIC COVERAGE

Twin domes made of nickel-containing stainless steel the place to meet at the Vancouver Olympics

PHOTOS: COURTESY OF ZIGGY WELSCH

One of the high-profile venues at the 2010 Vancouver Olympics never hosted an athletic event and yet GE Plaza's gleaming stainless steel domes were the focus of the redesigned Robson Square outdoor ice-skating rink that became a gathering place during the recent Winter Games.

The domes – a pair of 18-by-12-metre oval structures with tubular, triangle-shaped ribs that frame glass inserts – are suspended above each end of the rink surface like giant turtle shells, reflecting the sunlight and cast in spotlights for night time events.

"It's a real piece of art," says Ziggy Welsch, project manager for George Third & Son Ltd., the century-old British Columbia firm that built the domes. George Third provides an array of heavy structural steel solutions, or, as Welsch puts it, "everything from spiral staircases to stadiums to rides at Disney World."

The C$3-million domes were constructed using 304 (UNS S30400) stainless steel. 305 millimetre diameter pipe with a wall thickness of 13 millimetres, was used to build the rim. A network of 150-millimetre diameter pipe, with an approximately 10 millimetre wall thickness, formed the concave ribs that give the domes their shape.

Construction required three-dimensional computer modeling to carry out the complex compound cuts of the ribs. As Welsch notes, "every piece is somewhat different; there's a lot of complicated geometry, to say the least." He adds that welding the 304 components together was especially tricky: "It tends to distort more easily than mild steel, so more care is required"

Each dome weighs about 32 tonnes and had to be built in four pieces so that it could be transported by flatbed truck through downtown Vancouver to its destination. To ensure an exact fit on-site, the domes were pre-assembled in George Third & Son's plant in the city of Burnaby.

Two Vancouver-area companies, Epic Metalworks Inc. and Ebco Metal Finishing LP, finished the surfaces. Epic, which specializes in architectural metalwork, applied a brush finish to the components before assembly. This finish made it easier for builders to deal with the complex angles and reduced the polishing needed to remove scratches and brighten welds once the domes were assembled.

The rink surface opened to skaters in November 2009 and will be used for concerts and other events in the summer. The domes are at street level, exposed to the everyday grime of the city, while the floor of the plaza lies below the surrounding streets. The stainless structure supporting the domes is low-maintenance and provides a look that Welsch describes as "awesome."

George Third & Son worked on two other venues at the Vancouver games – ski jumps at Whistler and the speed skating oval at Richmond – but it was the domes that attracted the most attention. They were a favourite backdrop for television reports from the adjacent international media centre. As well, the plaza was a focal point for live music and celebrations.

"There were a few hundred thousand people in the streets every night during the Olympics," says Welsch, "and the plaza was the hub where people wanted to gather." Ni

A Touch of Class

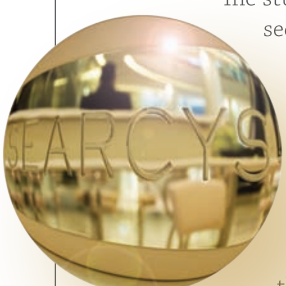
Brushed nickel sheet brings elegance and warmth to ***The Champagne Bar*** in London's Westfield shopping district

PHOTOS: COURTESY OF INTERBAR

Nickel can be used in a myriad of applications, from energy production to mobile phones, but inducing well-heeled shoppers to put down their designer bags, rest their weary legs, and enjoy a glass of champagne must be one of its more unusual uses.

The Champagne Bar at the prestigious Westfield Shopping Centre in west London – one of the largest indoor retail centres in Europe – has been enormously successful at enticing customers. More than 100,000 glasses of bubbly were served in its first year of operation, despite having opened (in October 2008) in the midst of the deepest UK recession since the 1930s.

The stunning bar is situated in The Village, an upmarket triangular section of the smart shopping complex, where premium brands such as Gucci, Prada and Tiffany lure customers through glass shop fronts that also boast gleaming nickel finishes.



Shoppers cannot help but be attracted by the Champagne Bar's gently glowing golden appearance and striking sculptural shape. They may be surprised to learn that the entire front of the bar is made of brushed nickel sheet, while the beading along the top and lower counters, and most of the metal pieces of the 35 stools around the bar are nickel plated.

Billy Pither is managing director of Interbar Ltd., the company that designed and built the bar in conjunction with renowned architects Hiscox Parladé. He explains why nickel was selected: "Westfield's design standard specified that we could not use stainless steel or classic cocktail-bar chrome to construct the bar. They insisted on nickel, chosen for its inviting appearance and feel. The colour of nickel is warmer than stainless steel and more appropriate for the desired atmosphere of the bar."

Architect Renshaw Hiscox, who designed the unique elliptical shape of the high-specification bar, liked the idea of designing with nickel. "We would have liked to use a lot more nickel on the bar," he says. "It gives the appearance of an old-fashioned finish. It is a good-quality material – quality is what the Champagne Bar is all about, and this shines through. It is perfect for high-end finishes."

Constructing a bar out of nickel was a first for Interbar. "We often use copper, brass and stainless steel. Brushed nickel was chosen because it is semi-shiny and welcoming," says Pither. Nickel is also tough and resists corrosion. It is aesthetically beautiful but at the same time enables the bar to be functional, as it does not require a lot of cleaning or polishing (apart from wiping with a damp cloth). "If the bar was made of copper, brass or bronze, it would need regular polishing," Pither points out.

The entire bar was constructed out of wood before the nickel sheets were cut to size and attached to the timber. The beading around the edge is made of nickel-plated brass in between the layers of the counters. "We bent the pieces of the brass to shape around the whole outline of the bar and then had them nickel-plated," explains Pither. The layer between the top and lower counters is covered with leather while the counters are made of Pyrolave, a French ceramic glazed lava rock.

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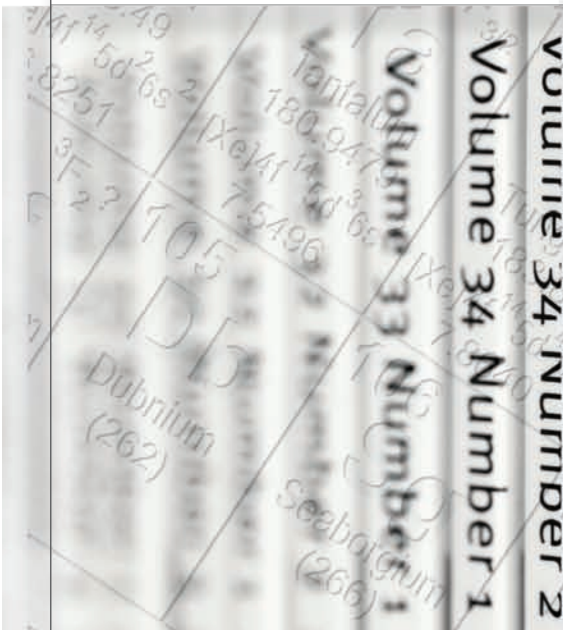

Registration Evaluation and Authorization of Chemicals

Preparing for a New Era in Chemicals Management

REACH

The Nickel Consortia	
Consortium 1	
Risk Assessed Substances	nickel metal, nickel chloride, nickel sulphate, nickel nitrate
Consortium 2	
Other Nickel Compounds	nickel hydroxycarbonate, nickel oxide, nickel dihydroxide, nickel sulfamate, nickel acetate, nickel sulphide, nickel subsulphide
Consortium 3	
Complex Nickel Materials	ferro-nickel (special preparation), nickel matte (intermediate),...

By November 30, 2010, all nickel compounds, including nickel metal (above 1,000 tonnes per year), will have to be registered under the EU law on the management of chemicals commonly referred to as REACH, an acronym for Registration Evaluation and Authorization of Chemicals.

To prepare for this deadline, the Nickel Institute and its member companies launched an implementation work plan as early as 2006 and succeeded in assembling three consortia. As shown in the table (left), there is one consortium each for risk-assessed substances, other nickel compounds, and complex nickel materials.

When the consortia were officially launched in January 2007, they were in the very forefront of the REACH process. The work since then has been labour–intensive (the equivalent of five people working full-time) and costly (budget: 6 million euros).

Organization of the Consortia

The scope of the REACH consortia covers guidance on pre-registration, data-sharing, classification of nickel and nickel compounds, preparation of registration dossiers, and evaluation of those dossiers.

The consortia include two types of members. The regular membership is aimed at EU producers and non-EU producers who export to Europe, as well as importers of nickel and nickel inorganic compounds. A different status, called Associate Membership, is assigned to representatives of important EU downstream users – this in recognition of the importance of information sharing and communication throughout the supply chain while preparing for the registration dossiers. There are currently 49 companies involved in at least one consortium.

The 2006 work plan developed for the 2007-2010 period covers effects assessment, exposure assessment, risk characterization, classification, physico-chemical properties, communication, program management, and reporting processes (in particular the International Uniform Chemical Information Database, or IUCLID, and the Chemical Safety Report, or CSR).

Early Registration Strategy

In 2009, the Nickel REACH Consortia put in place an early registration strategy and pushed ahead quickly on the nickel metal and nickel sulphate dossiers. Owing to the decade-long investment in risk assessment that preceded REACH, considerable data and a rich number of scientific references and chemical safety reports on these two chemicals were already available. As a result of completing the early registration for these two chemicals, the consortia was able to proceed quickly to a concentrated registration of chemicals that did not have the same detailed regulatory history.

In March 2010, the nickel metal and nickel sulphate dossiers were successfully registered – a major achievement for all the producers, importers and downstream users of nickel and nickel-containing substances.

The experience gained as a result of this exercise proved valuable for dealing with member companies and downstream users such as the stainless steel, alloy, plating and catalyst industries. As well, early registration allowed the Nickel Institute and all the members to become familiar with mandatory information technology tools such as IUCLID 5.2 software and the REACH-IT (information technology) system.

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PHOTOS: ISTOCKPHOTO © DANIEL LAFLOR, © PALI RAO, © CHRISTOPHER STOKES, © STUDIOVISION

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Managing the Process for Efficient Success

Completing the registration dossiers is resource-intensive, as are the data-sharing obligations under REACH. Fortunately, the Nickel REACH Consortia has developed various tools to aid in the finalization of joint submissions and to comply with the REACH goal of minimizing animal testing through the sharing of data.

To ensure animal testing is kept to a minimum, REACH authorities created the Substance Information Exchange Forum (SIEF). Different ways exist for SIEF members to get access to the data required for registration: they may join the appropriate consortium or obtain a Letter of Access or a License to Use – all at a cost, since those who developed the data in the first place had to pay for it. Thus the cost of generating the data is shared by all who make use of it.

In addition, communication tools such as the Nickel REACH Consortia web site (see table page 19) and "SIEF Flash" are available. These are relevant to the approximately 5,000 companies that have pre-registered nickel metal and other compounds. As of May 2010, fewer than 10% of those companies were active, though this is expected to change dramatically as the registration deadlines approach.

Companies that need to register their substances by November 2010 are invited to contact the Nickel REACH Consortia before Sept. 1, 2010. After that date, it will be difficult to guarantee timely access to the information.

Registration is not the End

Understandably, the Nickel industry's main focus has been registration process. However, REACH is an ongoing chemicals management regime and registration is not the end of the process; nor is November the only deadline.

Different chemicals are on different registration timelines (2013 or 2018), so activities related to substance information sharing will not stop. As well, new entrants (producers and importers) will have to register their products and make use of existing data. The information submitted in the registration dossier to the agency must be kept up-to-date. Every new use, new study, all new data must be reflected in updated registration dossiers as soon as possible.

Registration dossiers also provide new information on classification . Depending on the situation, member states or industry can submit to the European Chemicals Agency (ECHA) proposals for harmonized classification and labelling. This provides the Nickel Institute with a mechanism to propose revised classifications for nickel and nickel compounds.

Evaluation

The work of the Nickel REACH consortia already includes evaluation of the dossiers. Under the auspices of ECHA, two types of evaluation are performed: that of the dossier (including examination of testing proposals and a compliance check) and that of the substance. The evaluation of some nickel substances could become an important and challenging step for the

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OCCUPATIONAL EXPOSURE LIMITS IN THE EUROPEAN UNION:

How the nickel industry can contribute to the regulatory review process

ISTOCKPHOTO © ROBERT BYRON

Chemicals exist and are used for reasons. At the same time, the hazards must be recognized and the risks to environment, workers and consumers must be reduced to an acceptable tolerable level. The determination of what that risk is in any scenario is a difficult process and is always open to reinterpretation in light of new data.

In this context in May 2009, the European Union's Scientific Committee for Occupational Exposure Limits (SCOEL) to chemical agents made a recommendation for a single Indicative Occupational Exposure Limit (IOEL) of 0.01 mg Ni/m^3 (inhalable aerosol fraction) for nickel and its compounds based on respiratory carcinogenicity and toxicity. This value was also considered to be protective against possible reproductive effects.

The current nickel OELs values in force in the EU range from 0.01 mg Ni/m^3 for the nickel soluble compounds to 1 mg Ni/m^3 for the insoluble nickel compounds.

While industry agrees with the general approach used by SCOEL, the SCOEL proposed value does not take into consideration issues of particle size differences, nor does it differentiate between various nickel compounds. Accounting for these factors would lead to IOELs that could establish limits for certain compounds that were several-fold higher (i.e., less restrictive) while still being sufficiently protective of human health.

ISTOCKPHOTO © PIC4YOU

An IOEL value is science-based. It does not, and is not supposed to, take socio-economic and technical feasibility factors into account. For any chemical for which an IOEL value is established at the EU level, Member States must establish a national exposure limit value using the IOEL value as the base reference. In this context, socio-economic considerations are applied in accordance with national legislation frameworks, to arrive, when possible, at an exposure limit value that best reflects a balance between being sufficiently protective of human health, while being achievable and affordable.

Contribution of the Nickel Institute

The Nickel Institute is engaged at both the technical and socioeconomic levels to ensure that newly proposed and the finally adopted OELs for nickel and its compounds in different Member States are sufficiently protective of workers' health without being unduly conservative. The Nickel Producers Environmental Research Association (NiPERA), the scientific branch of the Nickel Institute, commented at the scientific OEL derivation regulatory phase.

In addition, the Nickel Institute has launched a technical feasibility study that will be followed by a socio-economic analysis with a third party. This will evaluate the business impact of possible SCOEL IOEL Values on the industries that use nickel and nickel compounds. The final outcomes of the study will then be shared with the national OEL setting agencies.

Occupational exposure data for the EU nickel producers and use sectors are currently being gathered. Consultation with the different nickel use sectors is foreseen in August 2010. The impact assessment study will be completed by October 2010. The ultimate study findings will be exposed to the nickel industry through a workshop organized by the Nickel Institute. Ni

FUEL CELLS: A work in progress

Fuel cells have long attracted interest because of their low impact on the environment and potential for energy efficiency. Unfortunately, technical problems and high costs have prevented this potential from being realized. Some of the costs are directly related to the traditional use of platinum as a catalyst. Over the past decade, researchers and entrepreneurs have brought down costs considerably and increased the reliability of fuel cells. The use of nickel both as a metal and an oxide has been an important part of these efforts.

There are many different types of fuel cells, but all of them use hydrogen or hydrogen-rich compounds as their fuel for generating electricity. Some fuel cells also generate heat which can be used efficiently.

There has always been a close association between nickel and fuel cells. It was Ludwig Mond (1839-1909) and his assistant Charles Langer who coined the term "fuel cells" in the late 19th century to refer to such cells that had been experimented with since 1838. Mond's fuel cell used industrial coal gas and air, with platinum as a catalyst. Mond went on to develop a process for producing high-purity nickel using nickel carbonyl as an intermediate chemical – a process still used today to refine nickel. The company he founded to commercialize the process, the Mond Nickel Company, is today part of the Vale group.

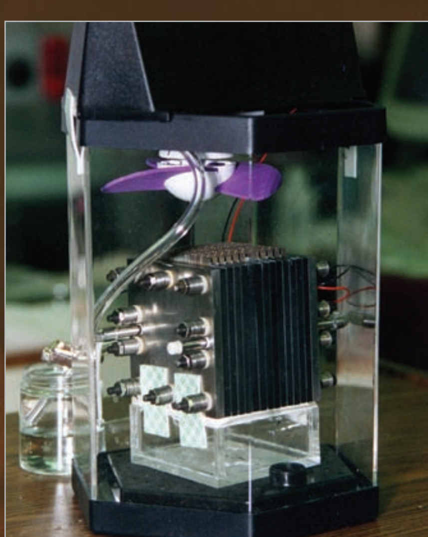
There are many types of fuel cells and most of them make use of nickel in some way. Researchers are trying to reduce the overall cost while maintaining or improving efficiency and reliability. For example, the Colorado School of Mines found that, for a proton exchange membrane (PEM) fuel cell using methanol as the source of hydrogen, a platinum-nickel alloy catalyst improved performance by a factor of two over pure platinum. However, even better catalysts must be found in order for PEM cells to be cost-effective.

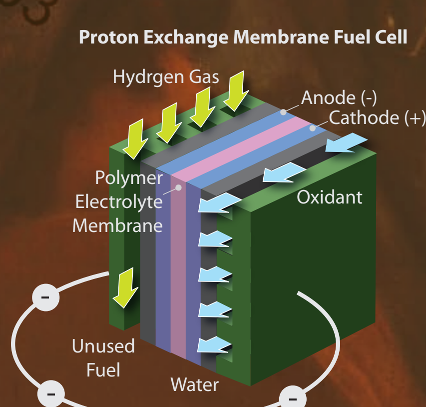
Solid Oxide Fuel Cells (SOFCs) can be used with many types of hydrocarbon fuels and yet can only operate at high temperatures. Research carried out at the University of Waterloo in Canada demonstrates how nickel is being used to meet this challenge. As Eric Croiset, associate professor in the university's Chemical Engineering Department, explains: "Our research involves developing intermediate-temperature [600-750°C] solid oxide fuel cells. Of particular interest are nickel-based anodes with ceria-based electrolyte that are coke-resistant for direct use of hydrocarbon fuels."

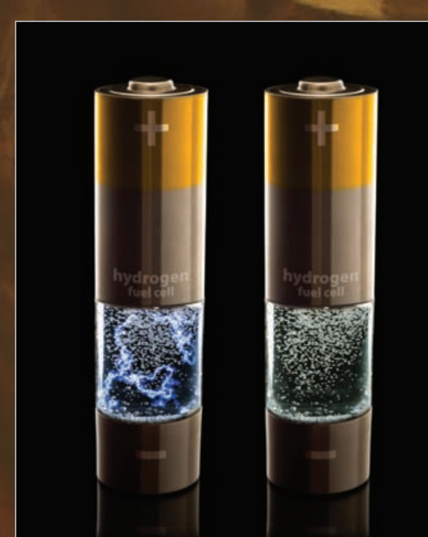
Indeed, such fuels can be internally reformed (that is, within the SOFC) because the electro-catalyst, nickel, is also an excellent catalyst for reforming reactions, converting hydrocarbon fuels such as methane directly into hydrogen and carbon monoxide. Internal reforming has the potential to simplify the overall process and make it more efficient.

Nickel, however, is also prone to carbon deposition (coking), which can lead to loss of performance and even permanent damage of the SOFC. The research team at Waterloo is adding small amounts of magnesium to limit sintering of nickel, which not only improves the stability of the cell but reduces the propensity to coking. The research is experimental, from the fabrication of a small laboratory-scale SOFCs to the testing and characterization of those cells. Modelling activities are also under way, especially regarding the identification of the kinetics of hydrogen and carbon monoxide electrochemical oxidation on nickel-based anode. The University of Waterloo is part of the Solid Oxide Fuel Cells Canada Strategic Research Network, which comprises seven universities, two governmental research associations, and 12 industrial partners.

If Ludwig Mond were alive today, he would not be surprised to find that nickel and fuel cells are so closely related.







◁ *Methanol Fuel Cell NASA.*

Could this be the future of fuel cells? ▷

PHOTO: ISTOCKPHOTO © ALEXEY DUDOLADOV

Green Cars: **Recycling Batteries**

The traditional car with gasoline internal combustion engine is equipped with the familiar lead acid battery. The battery is designed to deliver a burst of power necessary to start the engine, and is recharged while the engine is running; when the engine is not running, it can used to power the radio, lighting, windows, and so on. The lead acid battery in the U.S. is the single most recycled consumer product, with more than 90% of the lead having been recycled in recent years.

Hybrid vehicles such as the Toyota Prius, Honda Civic Hybrid and Ford Escape Hybrid use a conventional lead acid battery for the same reason as the combustion engine car, but they are also equipped with electric motors for propulsion of the car and a rechargeable deep-cycle battery. This second battery provides the driving force to the electric motors and must therefore be able to store considerable electrical energy. The electrical power train assists the gasoline engine. When the engine is idling or functioning at consistently low speeds, the battery can completely power the vehicle, reducing fuel consumption in the process. The drive-train management systems permanently optimize the use of the batteries or of the internal combustion engine or both to power the car.

Rechargeable nickel-metal hydride (NiMH) batteries are used in most of today's hybrid cars and offer major performance and environmental benefits. These include higher energy density and longer life than conventional lead acid batteries. The NiMH battery is also smaller and lighter, which adds to the fuel economy of hybrid cars.

The relatively small size of the NiMH battery brings additional economic and environmental benefits from the perspective of raw material sustainability. According to the Öko Institute (Institute for Applied Ecology) in Germany, a NiMH battery in a Toyota Prius contains 23% nickel, 36% steel, 18% plastics, 9% electrolytes, 7% rare earth metals, 4% cobalt, 2% other metals, and 1% polytetrafluoroethylene (PTFE).

The Öko Institute has assessed the life cycle of NiMH batteries and their use in hybrid electric vehicles (http://www.recharge-batteries.org/LCA_Ni-MH_in_Toyota_Prius__-_IARC2010.pdf); besides major gasoline savings, which were expected, there were significant recycling benefits. The study concludes that a hybrid electrical vehicle reduces global warming potential (GWP) by 29.6% due to reduced fuel consumption.

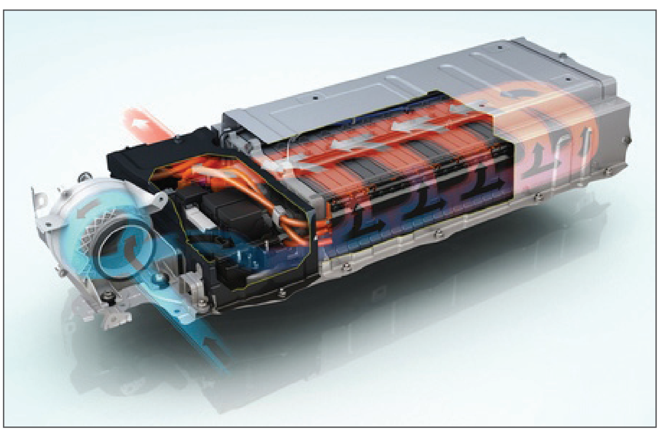


PHOTO: TOYOTA MOTOR CORPORATION

△ *Toyota Motor Corporation Prius battery showing the electric motor and electrical flows*

The battery industry is riding a major technological research and development wave in conjunction with the automotive industry to develop safe rechargeable lithium-ion batteries for automotive propulsion use. The high-voltage battery is key to the success of hybrid and full electric cars for reasons of cost, weight, reliability and long life. For all full electric vehicles, the battery determines the distance the vehicle can travel before it must be recharged. Battery demand forecasts suggest that lithium-ion batteries, in various forms, are likely to be used increasingly in hybrid and electrical vehicles. The lithium-ion batteries have an excellent energy-to-weight ratio, zero memory effect, and a slow loss of charge when not in use. They are smaller and lighter than other battery types for a given energy content, yet substantially more powerful. High-strength housing and various other measures, such as proper ventilation, ensure that the battery operates in ideal temperatures. The cathode in lithium-ion batteries will either be a nickel-cobalt-aluminum mix or a manganese-nickel-cobalt mix. Regardless of the type of cathode, the nickel content is around 2-6% by weight of the battery.

The relatively small size of the NiMH battery brings additional economic and environmental benefits from the perspective of raw material sustainability.

Both NiMH and lithium-ion batteries can be recycled. Through its award-winning zero waste and closed-loop battery recycling process, Belgium-based Umicore Battery Recycling (UBR) is the leading recycler of such batteries in the world. The company's process is dedicated to the safe recycling of NiMH and lithium-ion batteries and battery packs, transforming end-of-life batteries into secondary materials used for new battery manufacture.

Some of the UBR Process advantages:

- Rechargeable batteries, battery packs and other input materials are injected into a furnace without any pre-processing, thereby minimizing risk to workers.
- A gas cleaning operation designed to eliminate the formation of dioxins and furans.
- Well-controlled melting conditions so that a clean slag is produced which is suitable for use in construction or as aggregate for concrete.
- A cobalt and nickel refining installation where pure cobalt and nickel are produced. Cobalt can then be transformed into lithium cobalt dioxide $LiCoO_2$, used in the production of the new lithium batteries.

This technology has been attracting attention on a worldwide basis. In 2004, UBR received the Gold Award presented by the European Environmental Press (EEP) in recognition of its innovative environmental technologies. The awards are organized by the EEP in collaboration with Pollutec and the European Federation of Associations of Environmental Professionals. In 2008, UBR was selected as one of the ten most innovative companies by Dow Jones and Mountain CleanTech, and was recognized by the French non-profit organization Alliances for its environmental achievements. In 2009 both Industrie Technisch Management and the non-profit organization Sirris nominated UBR for Best Innovation.

UBR has a central battery recycling and processing facility in Belgium and a network of battery recycling drop-off points globally. This system allows for ease of collection while high efficiency in recycling. The European Battery Directive states that all batteries must be recycled and that recycling efficiency must be at least reach 50% by weight of its material content (defined as qualified recycled materials/outflow divided by spent battery materials/inflow). The EU Batteries Directive will be transposed in National Legislation by all Member States of the European Union.

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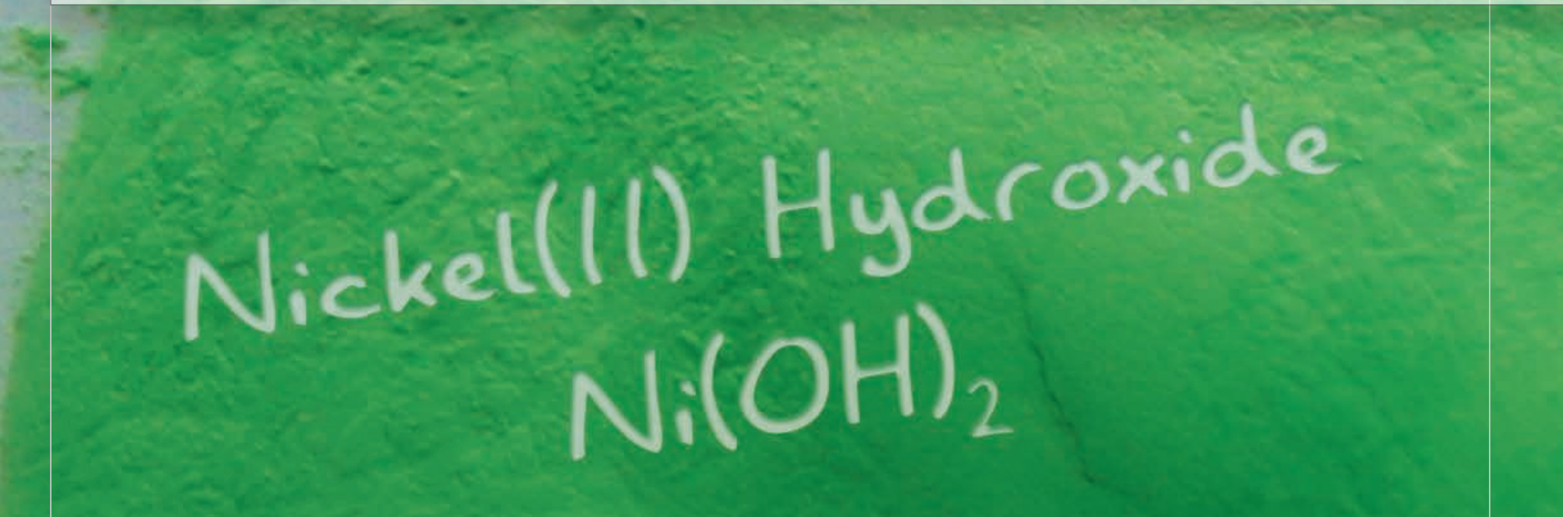


Enabling Essential Battery Technologies

The modern world is striving for greater efficiencies, lower emissions and less intensive use of materials. At the same time, industry is more dependent on chemicals than ever before. It is perhaps not surprising, then, that the world is going through a revolution in chemicals management.

The European Union legislation known as REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) is already having an influence on individual nations[1] and the world at large.[2]

The vast majority of these chemicals are unknown to consumers. To public officials responsible for chemicals, they are often known only by their chemical compositions and classifications. They are known for what they are, not for why they are used. To fill that knowledge gap, *Nickel* magazine is publishing a series of articles on nickel chemicals, starting with nickel(II) hydroxide $Ni(OH)_2$ and its cousin chemicals.

Energy, in addition to being essential to developmental aspirations, is the key to sustainability. The largest deployments of capital, contributions to grids, and impacts on the environment and health are associated with fossil fuels and nuclear and hydro energy. But change is in the air: on a smaller scale, the tools of work, communications and pleasure require energy storage that packs more stored power into increasingly smaller spaces.

There is constant investment, innovation and competition in energy storage and battery chemistries as various products are developed that optimize batteries for different uses: fast-charging, fast-discharging, constant voltage, high voltage, volumetric energy density, chemical stability, low self-discharge rate, ability to be recharged multiple times, reliability, and other criteria. In many important cases, however, a basic building block is nickel(II) hydroxide, taking advantage of nickel's electro-chemical properties and its relative abundance compared with chemicals based on platinum and related metals.

Nickel(II) hydroxide is produced in Europe and North America, though the majority is produced in Asia, where the greatest growth in production is also reported. As a basic battery ingredient, it is an insoluble green crystal (that is, before being transformed or doped with other chemicals to achieve the desired electrical and other characteristics). There are several routes to production, though all require high-purity metallic nickel (usually cathode nickel) and the main production process involves precipitation from nickel(II) salt solutions by means of alkali hydroxides. The finished product is shipped in secure containers to battery manufacturers.

Leading Battery Technologies

Nickel Metal Hydride (NiMH) and Nickel-Lithium (Ni-Li): While competition is growing (and a "hybrid" technology is, almost by definition, transitional), the reality is that NiMH is the dominant battery technology, and the dominant user of that technology is currently Toyota. The Japanese automaker has put 1.8 million Prius cars (now in their third generation) on the road; each has a battery pack that contains approximately 10 kilos of nickel in the form of nickel(II) hydroxide.The technology is reportedly very reliable: there is no Prius battery after-market as every battery pack is expected to last the lifetime of the vehicle.

That technology is expected to change, and candidates for replacement are in sight. Many of those, however, also rely on nickel(II) hydroxide. For example, the nickel-lithium battery being developed by Toyota and Panasonic is expected to deliver three times the energy per unit of volume. The chemistry has been proven though mass manufacturing remains a challenge since current, early-stage designs are complex. [3]

[1] see USA Toxic Substances Control Act reauthorization: http://www.epa.gov/oppt/existingchemicals/pubs/principles.html

[2] United Nations Strategic Approach to Chemicals Management/SAICM: http://www.saicm.org/index.php?menuid=2&pageid=256

[3] For more information: http://gas2.org/2009/10/06/new-nickel-lithium-battery-has-ultrahigh-energy-storage-capacity.

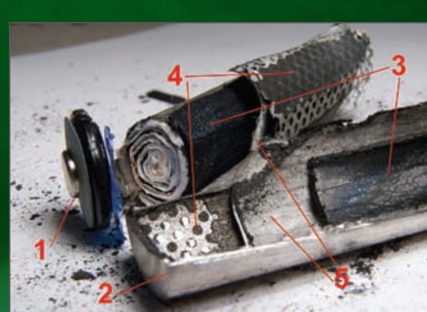
Nickel: Knowing Ni

Nickel Iron (Ni-Fe): It has been more than a hundred years since American inventor Thomas Edison developed the nickel-iron rechargeable storage battery, which uses nickel(III) oxide-hydroxide as the cathode, iron as the anode, and potassium hydroxide as the electrolyte. It is not the most impressive of battery chemistries by any means though the unit is robust and tolerant of abuses such as overcharge, over-discharge, short-circuiting, thermal shock, and vibration. Its service life can in fact exceed 20 years in such conditions. Traditionally, the battery has been used in the harsh operating conditions of mines, though currently it is being considered for use in wind and solar power. In those environments, the battery would accumulate energy during periods of high electrical charging but low demand, and discharge into the grid during low- or zero-charge periods.

Nickel Oxyhydroxide (NiOOH or NiOx): This is a new type of non-rechargeable battery sold under brand names such as Duracell Power Pix and Panasonic Oxyride. NiOx batteries excel in high-drain applications such as digital cameras and can provide up to twice the life of alkaline units.

Nickel Hydrogen (NiH_2): In May 2009, the original NiH_2 batteries of the Hubble Space Telescope were changed after more than 19 years of continuous service and the highest known number of charge/discharge cycles of any nickel hydrogen battery. This type is viewed as a kind of hybrid between a traditional battery and a fuel cell as the chemical activity takes place in a pressure vessel (up to 8,300 kPa/1,200 psi). Nickel hydrogen batteries are never going to be common, and yet in cases where high energy density, utmost reliability, and long service are required, they will find a use. Every major space probe and long-lived space enterprise (such as the International Space Station) relies on nickel hydrogen batteries that have nickel(II) hydroxide at their core. Ni

▽ *Disassembled Ni-MH AA cell. 1: positive terminal 2: outer metal casing (also negative terminal) 3: positive electrode 4: negative electrode with current collector (metal grid, connected to metal casing) 5: separator (between electrodes).*



Nickel(II) hydroxide $Ni(OH)_2$ is a precipitate formed when the hexaaquanickel(II) ion is mixed with aqueous ammonia.

Common name variants:
Nickel dihydroxide, Nickel hydroxide, Nickel (2+) hydroxide, nickelous hydroxide

CAS number:
12054-48 7

EINECS number:
235-008-5

Molar mass:
92.708 g/mol (anhydrous);
110.72 g/mol (monohydrate)

Appearance:
green crystals

Crystal structure:
hexagonal

Density:
4.10 g/cm^3

Melting point:
230ºC (anhydrous decomposition)

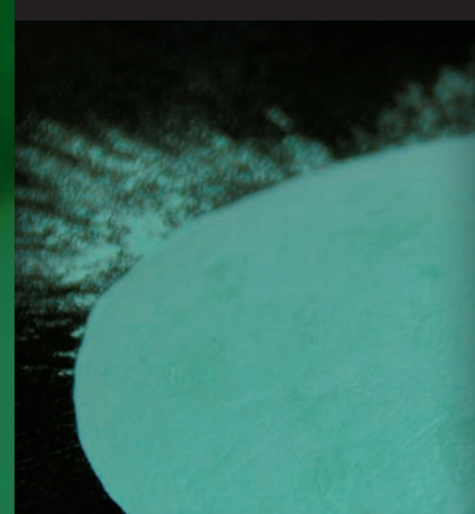
Water solubility:
insoluble

Solubility:
dilute acid, ammonia

Related chemical:
Beta-nickel hydroxide

CAS number: 11113-74-9

EINECS number: 234-348-1



PHOTOS COURTESY OF JINCHUAN GROUP LTD

PHOTO DISASSEMBLED AA BATTERY: CZATLANTIS

Coming Events:

Workshops in China

Later this year two very popular NI workshops will be hosted by the NI Beijing office in China.

September 2010:
Nickel Institute Food Industry Workshop

After an introduction to the Nickel Institute by the NI Beijing office, Nickel Institute consultant Gary Coates presents an in-depth look at stainless steels, the most commonly used material for food contact surfaces.

Among the topics discussed are:

- Introduction to Stainless Steels
- Avoiding Corrosion
- Good Design and Fabrication Practices
- Hygiene and Sanitary Standards
- Examples of Usage in Food and Beverage Production

There is a time for questions after each session and at the end. The seminar is suitable for food and beverage plant personnel wanting to learn more about the material they are using, fabricators and designers of systems and equipment, and universities and technical institutes.

November 2010:
Nickel Institute Architecture, Building and Construction Workshop

This workshop is presented by Nickel Institute consultant Catherine Houska and covers such topics as:

- Stainless steel and sustainable design
- Stainless steel selection, design and maintenance
- Finish options
- Interior, exterior and structural applications

For more information regarding venues and specific dates please contact the NI Beijing office:
cli@ni-china.org

Hybrid Car Batteries

cont'd from page 15

The current supply of NiMH batteries to be recycled is limited because the hybrid cars carrying them have been recently introduced on the market and batteries have a service life expectancy of about 10 years. However, UBR says it is prepared to meet the growing recycling needs of NiMH batteries in 6-10 years' time when the life cycle of 1-2 million batteries will have come to an end of service life. In preparation, 25 million euros has been invested in a 7,000-ton-per-year recycling plant.

Currently all the lithium-ion batteries UBR recycles originate from lap-tops, mobile phones and power tools. Recycling and processing facilities in several continents will be expanded once lithium-ion batteries from hybrid and electric vehicles start streaming in. At this stage, nobody can predict how fast demand will grow for the next generation of hybrids and electrical vehicles.

European Directives require all carmakers to demonstrate how every component in the vehicle will be recycled. UBR is in communication with most car manufacturers regarding the proper recycling efficiency of the NiMH and lithium-ion batteries, as required under the European Battery Directive. One thing is certain: Umicore's recycling process will boost the sustainability of hybrid and electrical vehicles for many years to come.

△ *In North America, Inmetco (http://www.inmetco.com) is the premier recycler of nickel-containing consumer batteries (pictured here) from the voluntary "Charge-up To Recycle" program of the Rechargeable Battery Recycling Corporation (http://www.call2recycle.org). In addition it receives and recycles electric vehicle battery packs that are highly valued for their nickel content. The nickel, chromium and iron from hybrid vehicle batteries and their cases is captured and becomes material for the manufacture of stainless steel.*

chemical compositions of nickel-containing alloys, stainless steels and compounds mentioned in this issue of Nickel

	Al	B	C	Co	Cr	Cu	Fe	H	Mn	Mo	Na	Nb	Ni	O	P	Pb	S	Si	SO_4	Ti	V	W	Other
$Ni(OH)_2$* p. 16, 17	-	-		0.5% max		3ppm max	5ppm max	-	-	-	0.03% max	-	59.5% min	-	-	2ppm max	-	-	0.01% max	-	-	-	-
S30400 p. 6	-	-	0.08 max	-	18.00-20.00	-	-	-	2.00 max	-	-	-	8.00-10.50		0.045 max	-	0.030 max	1.00 max	-	-	-	-	-
N01555 p. 20	-	-	0.07 max	0.05 max	0.01 max	0.01 max	0.05 max	0.005 max	-	-	-	0.025 max	54.0-57.0	0.05 max	-	-	-	-	-	rem	-	-	-

*typical specification

Champagne Bar *cont'd from page 7*

The matching stools fixed around the bar are standard Italian stools which were delivered with chrome-plated bases. "We removed the chrome and then they were nickel-plated on the base, the stem, the footrest, the studs on the backs, and on any visible metal parts," says Pither. "It was not a difficult procedure."

There were, however, a few obstacles to making the Champagne Bar with nickel. "We had a hard job sourcing nickel sheet," Pither admits. The nickel was eventually sourced via the Nickel Institute from Philip Cornes & Co, part of TW Metals in the U.K.

PHOTOS: COURTESY OF INTERBAR

Nickel sheet was not easy to work with, owing to its softness and tendency to bend "almost like lead", according to Pither. "In order to cut it to the correct size, our craftsmen had to keep the nickel sheet horizontal rather than working with it vertically, sandwiched between timbers to keep it flat. If they bent it too far, it would stay bent, so they had to work quite gently."

Allergic dermatitis due to contact with nickel sheet can potentially be a problem but not in this application either in the manufacture of the bar or in the end use. On site, the nickel still had blue protective plastic on it to prevent scratching, so the worker's contact with it was clearly limited. In regard to the patrons of the bar, none of the areas where the nickel sheet has been used are areas where there is prolonged contact with the skin.

So how are people responding to the Champagne Bar? "It has been hugely successful and everyone loves it," says Pither. People walk through that section of Westfield, find the bar right in front of them, so they sit down and have a glass of champagne. It attracts people because it looks so nice. We are proud of the Champagne Bar – I am a great fan of nickel and would be happy to use it again." Ni

REACH *cont'd from page 10*

nickel industry, in which case appropriate attention and resources will be required.

The nickel industry and the Nickel Institute will continue to live up to their registration and post-registration responsibilities. The safe and responsible use, re-use, recycling and disposal of nickel and nickel-containing chemicals depends on their doing so.

Resources

There are almost too many sources of information. REACH is a new and complex process and is being applied to tens of thousands of chemicals. The learning curve for both industry and regulators has been extraordinarily challenging and expensive. The Internet is a rich source of information and guidance on REACH and a few basic links relevant to this article are provided here: Ni

KEY LINKS	
Nickel REACH consortia	www.nickelconsortia.org
REACH-IT	http://echa.europa.eu/reach/software/reach-it_en.asp
SIEF	http://echa.europa.eu/sief/pre-SIEF_en.asp
ECHA	http://echa.europa.eu

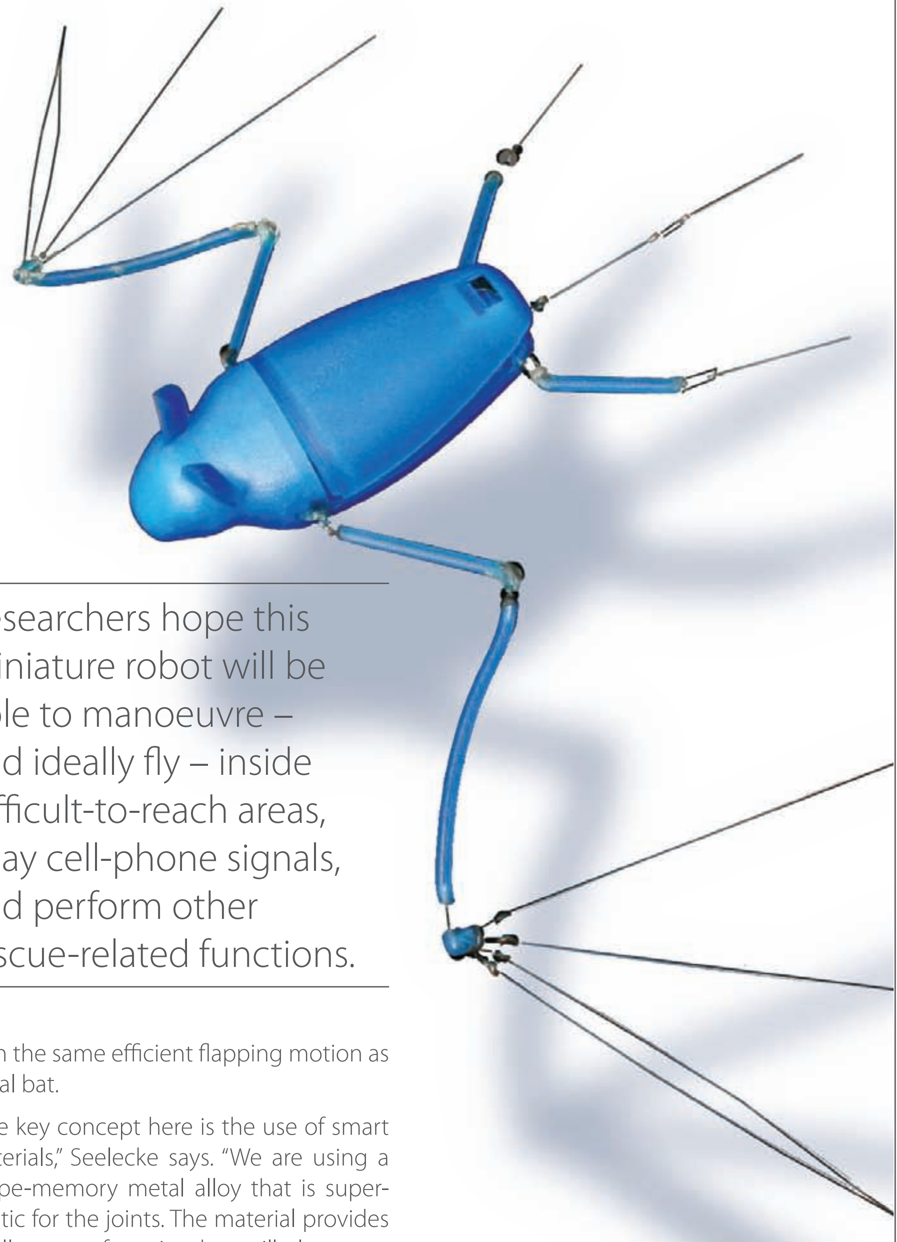
Metal Muscles

Researchers at North Carolina State University are using nickel-titanium shape memory alloys to create a new generation of remote-control flyers.

No longer mere curiosities, nickel-titanium shape memory alloys (SMAs) are being used in industrial applications, such as in bridges in earthquake-prone regions (as discussed in our December 2009 issue), while, at the research level, scientists continue to explore their potential in new – and sometimes strange – ways.

Case in point: researchers at North Carolina State University are using SMAs to develop robotic bats which, thanks to their maneuverability, should be able to perform search-and-rescue functions in collapsed buildings and other enclosed spaces.

At least that's the plan.



Researchers hope this miniature robot will be able to manoeuvre – and ideally fly – inside difficult-to-reach areas, relay cell-phone signals, and perform other rescue-related functions.

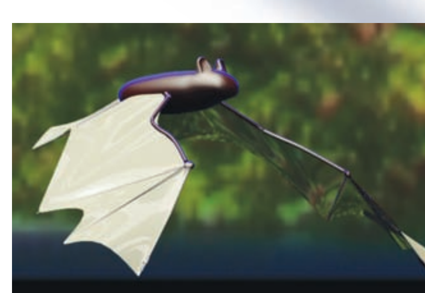
Weighing less than six grams, the "robo-bat," as it's called, fits easily in the palm of your hand. The skeleton's joints are made of Nitinol (UNS N01555) – a super-elastic shape memory alloy that deforms rapidly under stress yet regains its original shape without heat treatment when the stress is removed, while the so-called muscular system makes use of another nickel-titanium alloy that responds to electric current.

"This shape memory alloy responds to the heat from electricity," explains Stefan Seelecke, the associate professor overseeing the project. "The heat affects wires the size of a human hair, causing them to contract like metal muscles. During the contraction, the powerful muscle wires also change their electric resistance, which can be easily measured. When the smart metal wire cools it returns to its original shape.

"We are trying to mimic nature as closely as possible because nature is very efficient," Seelecke says. "In the case of micro-aerial vehicles, nature tells us that flapping flight – like that of a bat – is the most effective means of motion." Indeed, the joints, muscular system and wing membrane of the robo-bat are designed to allow it to fly with the same efficient flapping motion as a real bat.

"The key concept here is the use of smart materials," Seelecke says. "We are using a shape-memory metal alloy that is super-elastic for the joints. The material provides a full range of motion but will always return to its original position – a function performed by many tiny bones, cartilage and tendons in real bats."

Besides serving as a surveillance tool with practical applications, the robo-bat could contribute to our understanding of aerodynamics. Says Seelecke: "It will allow us to do tests where we can control all the variables and finally give us the opportunity to understand the aerodynamics of flapping flight." Ni



△ *Robo-bat – the use of smart materials.*

IMAGES: BYRON NASH / "EDIT AT JOE'S"