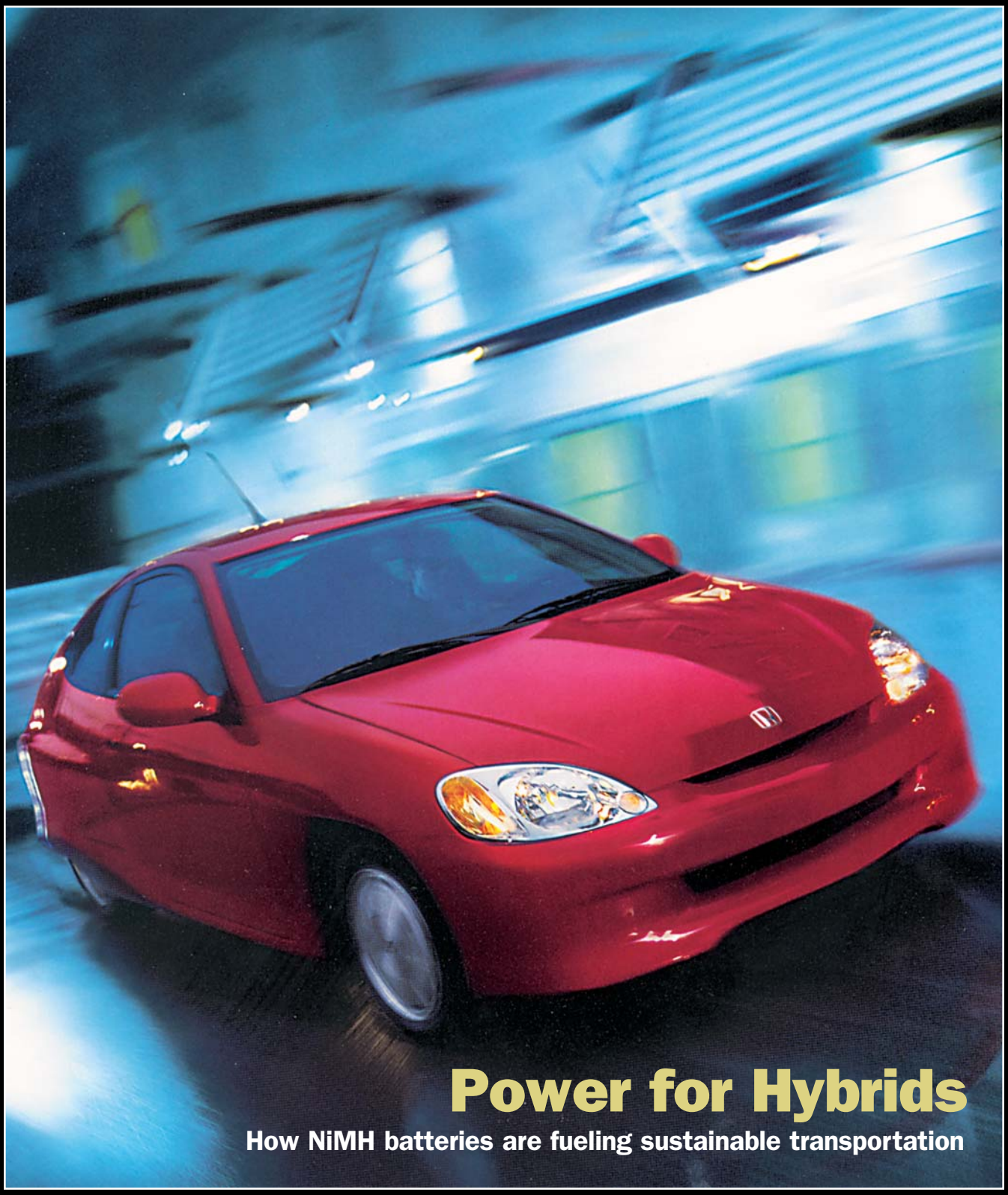
NICKEL

Scotland's new tidal generators

A new ultra-fine nickel powder

MARCH 2004 VOLUME 19, NUMBER 2 THE MAGAZINE DEVOTED TO NICKEL AND ITS APPLICATIONS



Power for Hybrids

How NiMH batteries are fueling sustainable transportation

NICKEL

Volume 19, Number 2, February 2004

The Magazine Devoted to Nickel and its applications

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Cover photo courtesy Honda.

The next issue of Nickel Magazine will be published in July 2004.

A Leap Forward

PUBLICATION OF THIS ISSUE OF NICKEL MAGAZINE COINCIDES WITH THE RESTRUCTURING of two associations that represent a large portion of the global nickel-producing industry.

The Nickel Institute (see details on page 2) brings together, under a single membership and management structure, the exemplary knowledge-generating and knowledge-disseminating capabilities of of the Nickel Development Institute (NiDI) and the Nickel Producers Environmental Research Association (NiPERA). The result is a leap forward because it positions the nickel-producing industry to better meet the anticipated future needs. Members of this single association, which represents 70% of global nickel production, can now act collectively in an integrated manner. The intent is that by presenting one common strategic direction, the nickel industry will get a fair hearing not only scientifically, but politically speaking as well.

Tapping the renewable energy potential of ocean currents and tides.

HONDA

This is a significant development that has long been contemplated, but has only recently been accomplished, thanks to the leadership of Chris Pointon, Chairman of the Nickel Institute and Dr. Ivor Kirman, President.

What does this reorganization of two nickel associations mean for the readers of *Nickel Magazine*?

Not a lot. Changes will be subtle and evolutionary, but you will probably notice an expanding mandate over the next few issues. You will begin, for example, to read more discussion of issues that relate to the sustainable use of that unique natural resource that enriches all of our lives – nickel. These include such topics as energy efficiency, environmental impact, hazard identification, risk assessment, resource efficiency, waste minimization and recycling.

In this issue, for example, we report on electroless nickel coatings that provide an environmentally sound alternative to chromium-nickel plating (see page 16).

From the transportation sector, we have a report on the enabling role that nickel is playing for Airbus and Boeing in their quest to build lighter, more fuel-efficient commercial aircraft (see page 12). We also report on how nickel is making it possible for automotive engineers at Honda and Toyota to make commercial hybrid electric vehicles (page 8) which have so-called "well to wheel" efficiencies that are significantly higher than conventional internal combustion engine vehicles. Both of these applications contribute to a more sustainable transport sector.

The energy sector of the global economy is another beneficiary of the unique properties of nickel and in this issue (see page 4) we report on an emerging technology that will see huge machines, submerged in seawater, begin to tap the limitless power of ocean tides and currents. Stainless steels that contain nickel and molibdenum are often an ideal choice to battle the corrosive action of seawater in these applications and will be essential if this technology is to advance.

We hope that you continue to enjoy reading about the latest applications of nickel worldwide and we encourage you to think about the important role this essential natural resource plays in enabling a more sustainable future. The Nickel Institute is dedicated to communicating that knowledge which is required for nickel to be used effectively, appropriately and sustainably. We look forward to receiving your suggestions for future articles that communicate this knowledge.

Here's to a brighter future.

Patrick Whiteway

Editor

inuse

THE LATEST NICKEL APPLICATIONS WORLDWIDE

Renewable Energy from the Tides

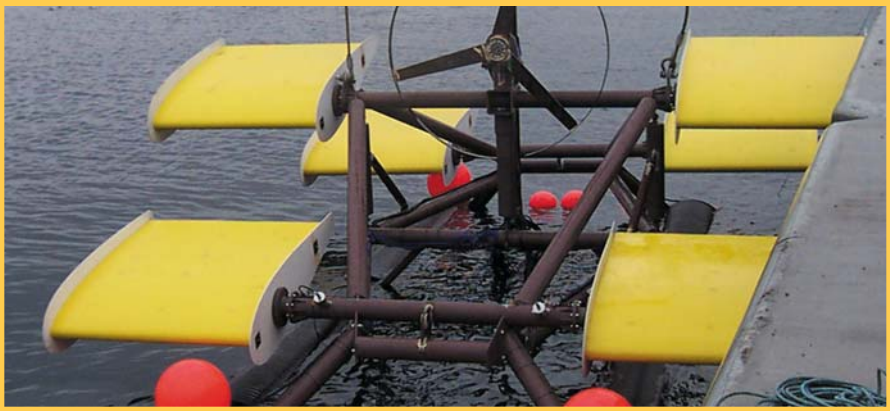
The race to harness the tides using submerged turbines requires stainless steel components

The Pentland Firth is a 23-kilometre-long channel that separates the Scottish mainland from the Orkney Islands and connects the North Sea to the North Atlantic. It's as little as 10 kilometres wide in places and, when the tidal flow peaks, it generates more energy than the combined output of the world's oil wells at any given moment.

Scientists and engineers are racing to devise underwater turbines that can harness the power of waterways like the Pentland Firth, providing access to a clean, renewable and almost unlimited supply of electricity. And nickel-containing alloys will play a key role in ensuring their innovations can withstand years of exposure to seawater.

"Our chief driver (in selecting materials) is clearly the corrosive sub-sea environment," notes George Gibberd, engineering manager for Marine Current Turbines Ltd (MCT). "We are considering the use of corrosion-resistant materials for critical items. For long-term reliability, we can't use anything else."

The British company has produced a 130-tonne prototype turbine that looks – and operates – like an underwater windmill. An 11-metre-long rotor blade is attached to a piling embedded in the seafloor. Dubbed the Seaflow Project, the 300-kilowatt turbine was installed off the south coast of England in June 2003. The rotor and gearbox are attached to a collar that can be lowered into the ocean, leaving only the top of the pylon protruding above the waves.



A 22-TONNE PROTOTYPE of an undersea turbine, designed by engineers at The Robert Gordon University in Aberdeen, Scotland. Called the Sea Snail, it is capable of generating up to 150 kilowatts of electricity.

THE ROBERT GORDON UNIVERSITY

LIKE AN UNDERWATER windmill, this 130-tonne prototype turbine was installed off the coast of England in June 2003 by the British company Marine Current Turbines Ltd. The unit, equipped with rotor blades 11 metres in length, sits on a piling embedded in the seafloor.

MARINE CURRENT TURBINES LTD.

The prototype incorporates stainless steel components and claddings in "selected specialist areas, where their use is absolutely critical," Gibberd reports. About a tonne of stainless steel cladding protects the guides and runners used to lift and submerge the rotor assembly. Stainless plugs, access hatches and seals were used where corrosion was a concern.

MCT is designing a larger, megawatt-sized version as it strives to commercialize the technology within a couple of years. "We do have a variety of stainless steels and nickel-based, high-strength fasteners in mind as potential candidates," Gibberd says. "We need highly pre-tensioned bolts for fatigue purposes, and the standard steels are prone to embrittlement in the environment. We may also be using stainless wire ropes for lifting mechanisms … But we also have to consider the implications of using noble metals in a plant having a high volume of plain carbon structural steel."

Engineers at The Robert Gordon University in Aberdeen are developing a smaller moveable, turbine to produce electricity on the ocean floor. A 22-tonne prototype capable of generating up to 150 kilowatts, known as the *Sea Snail*, will be tested in those swift-flowing waters off the Orkney Islands this spring.

Built on a limited budget and designed only for a short-term test, the *Sea Snail* contains no stainless. But future versions are sure to contain nickel alloys, says engineer Alan Owen of the university's Sustainable Energy and Environmental Research Institute.

Continued on page 15

More photos and text are available at the URLs given at the end of each article.

Harder Stainless Steel

A new plasma carburization process hardens austenitic stainless steel

Tanaka Limited of Osaka, Japan, has developed a plasma carburization treatment that hardens the surface of austenitic stainless steel nuts and bolts.

Carburization of austenitic stainless steel is typically a challenge: at high temperatures of 550 to 850° C, chromium carbides are generated within the metal, and these are then precipitated at grain boundaries where they can lead to intergranular corrosion.

However, because the process developed by Tanaka operates at a much lower temperature of less than 500° C, solid solution-strengthened carbon is formed without the formation of chromium carbides.

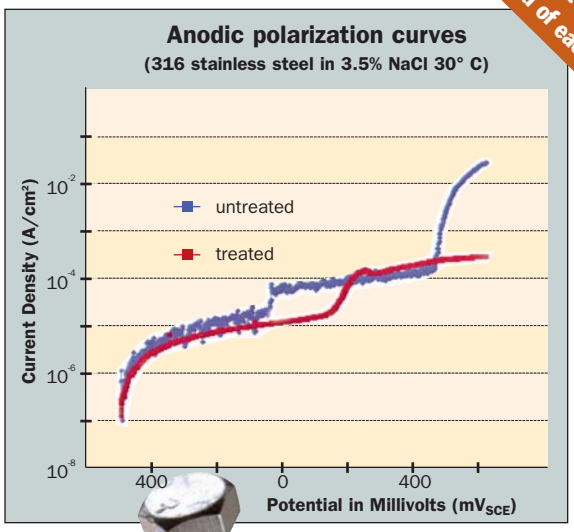
"For austenite-stable materials, such as S31600 and S31700, the process has a beneficial effect," says Tsunenari Murakami, general manager of Tanaka.

The new carburization process improves the wear resistance, galling and seizing characteristics of stainless steel in nut-and-bolt applications.

Harder nuts and bolts produced by this process can be used in food & beverage processing equipment, in which lubricating oils are not allowed, and in medical equipment applications, where hygiene is essential, says Murakami.

Carburized stainless steel has been used commercially by a major manufacturer for a threaded lid on a beverage processing vessel. The hardened lid prevents galling and seizing, which would result in wastage of the product being processed in the vessel.

The anodic polarization curve for S31600 is shown in the accompanying diagram.



TANAKA LIMITED

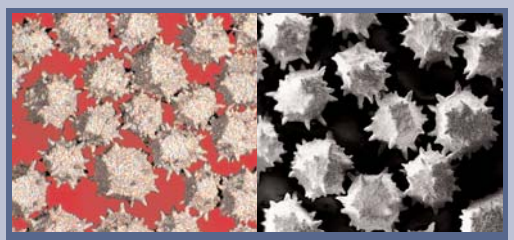
MORE INFO: www.nickelmagazine.org/0304/5a.htm

Nickel Coating Improves Tool Life

Better abrasion resistance key to making rock-cutting tools last longer

A new nickel-based coating for diamonds is improving the performance and lengthening the life of stone-cutting tools.

The unique design requirements of diamond tools used to cut stone and concrete make them vulnerable to wear and tear. The tools require soft metal bonds for free cutting, but these same bonds – containing a high percentage of copper or copper alloys – are susceptible to erosion and poor diamond adhesion. Many of the diamonds are lost before the tool has reached the end of its useful life.



Industrial diamonds, coated with a 20-micron-thin layer of nickel alloy, reduces diamond "pull-out" in abrasive cutting applications.

The MBS™ SB diamond developed by Ohio-based GE Superabrasives overcomes this flaw with an innovative double coating design consisting of a nickel alloy and an intermediate layer. The alloy coating improves adhesion between the diamond and the soft metal matrix, while the intermediate layer acts as a glue between the coating and the diamond.

"Historically, soft-bond diamond tools have relied on uncoated MBS diamond as the abrasive," says Shridar Kompella, an engineer for GE Superabrasives. "Uncoated diamond, however, does not interact with the copper-alloy in the matrix upon processing and is prone to popping out prematurely. The SB coating enhances retention of the MBS SB diamond in the bond and helps to ensure the optimal use of a diamond."

GE considers the composition of the nickel alloy and intermediate layer proprietary.

Coating diamonds for improved performance is a relatively recent technical advance designed to address industry demand for better diamond retention and longer tool life. Before coatings were developed, the popping out of diamonds was a regular occurrence caused by poor chemical bonding between the diamond and the metal matrix, chemical attack during the sintering, and/or fractures resulting from inherent weaknesses in the diamond.

The most common metal coatings for diamonds are chromium and titanium. These metals resist chemical attack and protect the diamond's strength and surface. They also have a high level of metallurgical compatibility with the common bond matrix elements, such as cobalt, used in many diamond tools.

The nickel alloy coating is different because it works specifically with soft metal bonds used to enhance free-cutting capabilities (trimming marble, granite or ceramic tiles, for instance). For this application, nickel provides a strong metallurgical compatibility with the copper matrix and abrasion resistance in the vicinity of the diamond. GE Superabrasives claims the marked increase in diamond retention results in significantly longer tool life, lower power consumption and superior cutting ability.

GE SUPERABRASIVES

MORE INFO: www.nickelmagazine.org/0304/5b.htm

New Powder Metal Applications on the Increase

Cost-competitive automotive applications are fueling demand for finer nickel powders

Two new nickel powders are enabling manufacturers to make strong, dense auto parts more economically than those crafted from wrought iron or stainless steel. These new powders increase density, improve flexibility, and provide greater strength and hardness in powder metal parts, compared with Type 123 nickel powder, which has been the industry standard since the 1960s.

STAINLESS STEEL FLANGES, such as these, dramatically reduce the leakage of exhaust gases at the junction of the exhaust system and the engine manifold.

INCO SPECIAL PRODUCTS

Inco Special Products (ISP), a division of Inco Ltd., developed the nickel powders, which are known as Type 110 and Type 270.

Type 110 powder contains extra-fine, discrete spherical particles of nickel that are tightly sized in the range of 1 to 2 microns. The finest nickel powder commercially available for powder metal applications, it is designed for high-performance applications. The extra-fine particle size provides greater shrinkage capabilities, which in turn significantly increase the density of the powder metal part. The finer particle size also allows for greater diffusion of the nickel, resulting in a more uniform microstructure with greater toughness and flexibility.

Type 270 powder is a chain-like network of fine nickel particles produced to tight physical tolerances. When used to produce pressed or sintered powder metal parts, Type 270 provides increase strength, hardenability and fatigue resistance in nickel steels; it also increases the dimensional control and diffusion, which leads to higher ductility and toughness in low-alloy steels.

As a result of recent developments in powder metallurgy, the use of powder metal parts has risen dramatically. Almost any high-volume, intricately crafted part that is highly stressed and requires a high degree of machining is a candidate for powder metal production. Auto parts produced using powder metals include gears, gear carriers, clutch plate holders, rotors, synchronizer hubs, and some braking components. The average North American-made sport utility vehicle (SUV) has about 20 kilograms of powder metal components, and some models contain as much as 30 kilograms. The applications in the automotive industry are so numerous, it uses about 70% of all iron powders produced.

Products manufactured using powder metals first surfaced about 50 years ago in response to changes in the automotive industry. Manufacturers were compelled to find ways to reduce manufacturing costs as competition in the automotive sector increased and profit margins decreased.

Until the late 1950s, all steel automotive parts were machined using either cast iron or wrought steel. Even though these parts possessed superior characteristics, such as fully dense structure, they were expensive to manufacture, owing to increasing labour costs and the waste generated in machining the part. Manufacturers of auto parts responded by using powders, which were pressed into moulds and heated. This proved economical since a large volume of parts could be created at one time and the capital cost of doing so was lower than the cost incurred by using traditional methods.

Initially, powder metal parts consisted of iron powder, but as the applications became more various, other metal powders, including nickel, copper and molybdenum, were developed and added for special uses. Today, powder metal parts are manufactured using powders typically containing 96% to 98% iron powder and 2% to 4% nickel, copper and/or molybdenum powders.

ISP began manufacturing Inco Type 123 nickel powder in the 1960s. It is a fine, high-purity powder containing discrete particles ranging in size from 3.5 to 4.5 microns, and is produced using Inco's carbonyl process.

Type 123 powder is combined with iron powder, then pressed and sintered to make low-density auto parts. It also binds well with tungsten carbide to manufacture diamond tools and is used as a binder metal with tungsten to manufacture a wide range of other parts. When used as an alloying element in powder metal parts, Type 123 improves strength, hardenability, fatigue characteristics.

Improved ductility and increased toughness are also achieved as the nickel powder defuses into the steel to form nickel-rich phases. It also promotes shrinkage during the sintering process, which leads to higher density in powder metal parts. And since it promotes shrinkage, Type 123, when used in conjunction with iron and copper powders, can counteract the expansion of copper. As such, nickel powders can provide dimensional control during the sintering process.

MORE INFO: www.nickelmagazine.org/0304/6.htm

INTRICATE COPPER-NICKEL sprockets that operate in diesel engine injection pumps are now made using powder metallurgical techniques.

CHRYSLER CORPORATION

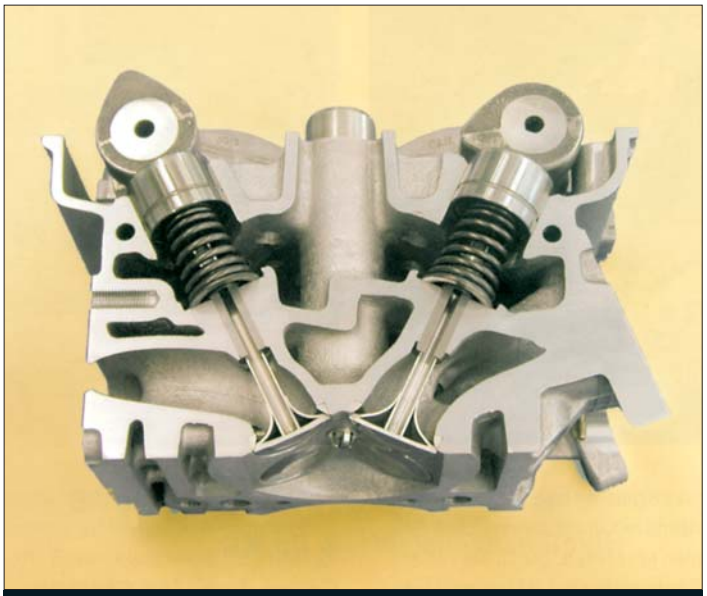
Reducing Fuel Consumption

Hollow engine valve made of nickel alloy wins top prize for innovation

A lightweight valve made from a nickel alloy has won first place in the Steel in Research and Development category of the 2003 Steel Innovation Prize.

The German steel industry introduced the annual award in 1989 to promote innovative applications and ideas involving steel. Last year, there were 678 contestants but only 12 winners in various categories. The categories include products made of steel, research and development, steel for the construction industry, and design.

The award-winning valve, made from N06601 containing 60% nickel, was designed by Stuttgart-based Mahle Ventiltrieb to help meet the demand for a lightweight, cost-effective valve in combustion engines.



NICKEL ALLOYED high-temperature, high-strength N06601 was used by the German company Mahle Ventiltrieb to design lightweight engine valves that are 30-50% lighter than conventional valves. The result is lower fuel consumption and fewer exhaust emissions.

MAHLE VENTILTRIEB

The choice of material was based on several, often conflicting requirements, says project manager Marcus Abele. The material had to be suitable for cold forming and laser-beam welding and, at the same time, withstand extreme thermal and mechanical stresses within the corrosive atmosphere of the engine. At average engine speeds and temperatures of up to 950° C, the valves open and close 30 times a second.

The new valve is 30-50% lighter than conventional models, reducing the mass that must be moved in the valve's actuating mechanism and, in turn, creating less frictional drag in the engine. Less friction and lower weight translate into less fuel consumption, fewer exhaust emissions, a higher allowable engine speed, and reduced wear on the engine.

"Customers are already showing interest in the lightweight valve," says Abele. "The first products are to go into volume production in 2005."

In the past, attempts to develop a lighter valve have involved ceramics, titanium and titanium aluminide. However, ceramics are prone to cracking under high loads, and titanium materials must be coated so that they are tribologically compatible with the other components in the valve. High material costs, as well as the high costs of manufacturing and testing, discouraged further development of these materials.

Another difference between the new valve and conventional valves is the structure. The Mahle valve is hollow with a high-precision nickel alloy shaft. The valve ball and plate are manufactured by a multi-stage forming process using N06601 sheet with a thickness of 0.8-1.8 mm. The individual components are connected to each other by laser-beam welding, and the hollow areas of the exhaust valves, which must be able to withstand high thermal stress, are filled with sodium to ensure thermal conductivity.

By using high-precision components, the amount of mechanical processing required is about a quarter of what is required for a valve manufactured by forging.

It was demand for a suitable, reasonably priced valve for combustion engines that triggered development of the prize-winning valve in 1998. The key innovation, says Abele, was the use of sheet metal parts. After developing a prototype, Mahle filed patent applications for the valve, both in Germany and internationally, then began a rigorous design and testing program, including a vehicle test covering more than 80,500 km.

In 2001, Mahle presented the new valve to the industry at the SAE World Congress in Detroit, Michigan, U.S.A., and the Engine Symposium in Vienna, Austria.

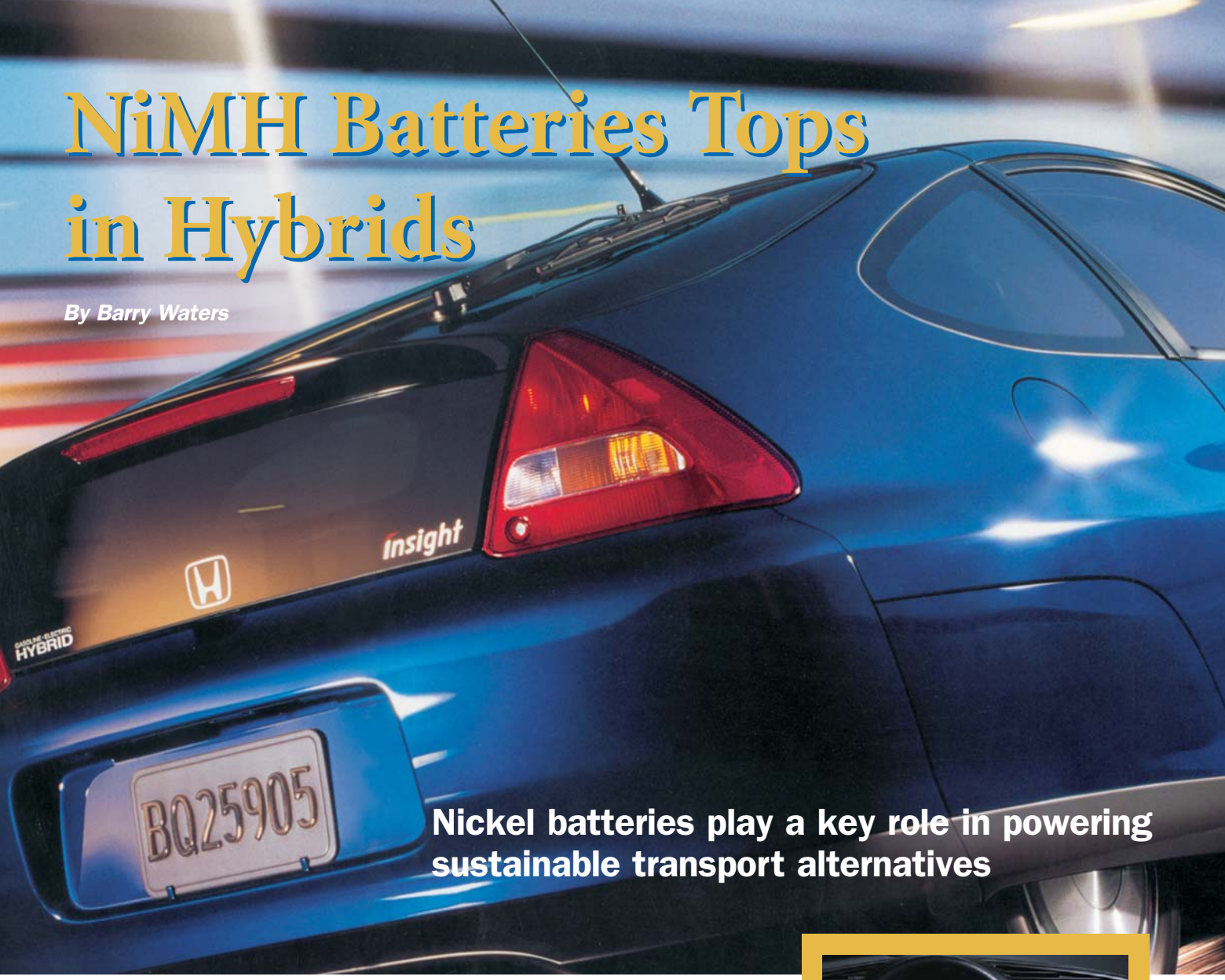
MORE INFO: www.nickelmagazine.org/0304/7.htm

Other German steel innovation awards (left) were awarded in 2003 to Miele for the design of a nickel stainless steel washing machine drum; to the companies Cool-System Bev. GmbH and Zeo-Tech GmbH for a self-cooling nickel stainless steel beer keg; and to Viega for the design of a nickel stainless steel press fitting system.

STAHL-ZENTRUM

NiMH Batteries Tops in Hybrids

By Barry Waters



Nickel batteries play a key role in powering sustainable transport alternatives

Technological development has reduced the size, weight and cost of the nickel metal hydride (NiMH) battery packs used in hybrid electric vehicles (HEVs). Relatively compact in size, they now have sufficient power, reliability and life expectancy to have been selected for the majority of mass-produced HEVs, such as the Honda *Insight* and *Civic*, and Toyota *Prius*.

Further improvements will increase the number of HEVs from the hundreds of thousands that are now on the road to millions in the future. The NiMH battery has made possible a large reduction in vehicle pollutants, while improving the utilization of scarce energy resources. In the future, when renewable energy is used to generate hydrogen for fuel cell vehicles, a hybrid design using NiMH batteries will be key to achieving efficient energy usage and to powering sustainable transportation.

These are some of the conclusions presented at the 20th International Electric Vehicle Symposium and Exposition, or EVS20, held in Long Beach, California, U.S.A., in November 2003. The event is the premier international event for the electric drive industry, and the theme of the 2003 symposium was "powering sustainable transportation." EVS20 featured exhibits by more than 100 international electric drive businesses, the display of 60 battery, hybrid and fuel cell vehicles available for testing, and presentations by more than 200 of the world's leading authorities on business, technical and policy issues.

The technologies that may ultimately drive the conversion from the internal combustion engine to electric drive systems were reviewed comprehensively. In addition to reduced vehicle emissions, such technologies open up the possibility for greatly improved fuel efficiency and, ultimately, the use of hydrogen fuels.

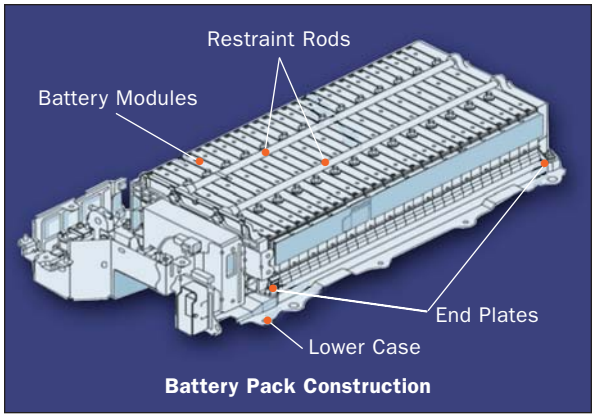
The Honda Insight (above), one of three commercially-available hybrid electric vehicles manufactured by Honda, was available for test-driving at EVS20.

HONDA INSIGHT

One of the yardsticks used to assess the environmental cost of a technology is the

"well to wheel" efficiency. This expresses the overall efficiency of an energy source, from extraction from the earth to when it turns the wheels of a vehicle. A modern, conventional automobile has an overall efficiency of only 14%, according to Toyota. The first-generation *Prius* HEV attains 28%, and the second-generation 2004 model, 32%. This compares with the target efficiency for Toyota's fuel cell hybrid vehicle prototype of 42% (assuming hydrogen fuel is derived from compressed natural gas).

All these vehicles increase their efficiencies by recapturing energy lost to friction through conventional braking by a process called "regenerative braking." And while there are various alternative ways to capture this energy, Honda and Toyota, the only suppliers of mass-produced HEVs on the market, have chosen NiMH secondary batteries.



Battery Pack Construction

NiMH batteries use nickel-oxyhydroxide doped with various proprietary elements as the positive electrode. The electrolyte is normally aqueous potassium hydroxide. The negative electrode is actually hydrogen contained as a hydride of a nickel alloy. Other metals in this alloy could be lanthanum or certain transition metals, including vanadium, titanium and zirconium. Hydrogen is absorbed at this negative electrode to form the nickel metal hydride during charging. During discharge, the hydrogen is released and oxidized to water.

Papers presented by Panasonic and Toyota at the symposium detailed the advances in the latest generation NiMH batteries. The prismatic module construction of the new battery allows superior heat-releasing performance and ease of installation. Used for the 2004 Toyota *Prius*, this battery, at 30 kilograms, is 25% lighter than its predecessor. It has an eight-year warranty, but the expectation is that it can last 15 years.

NiMH batteries also powered an all-electric vehicle fleet that was tested by Southern California Edison. Five test vehicles out of the 320-vehicle fleet were selected for detailed testing, and the conclusion was that a 210,000-to-240,000-kilometre NiMH life could be expected. In five years, the 320 electric vehicles logged more than 110 million kilometres, eliminating about 915 tonnes of air pollutants and preventing more than 4,100 tonnes of tailpipe emissions.

Barry Waters is Group Director, Nickel Use Support and Development, for the Nickel Institute

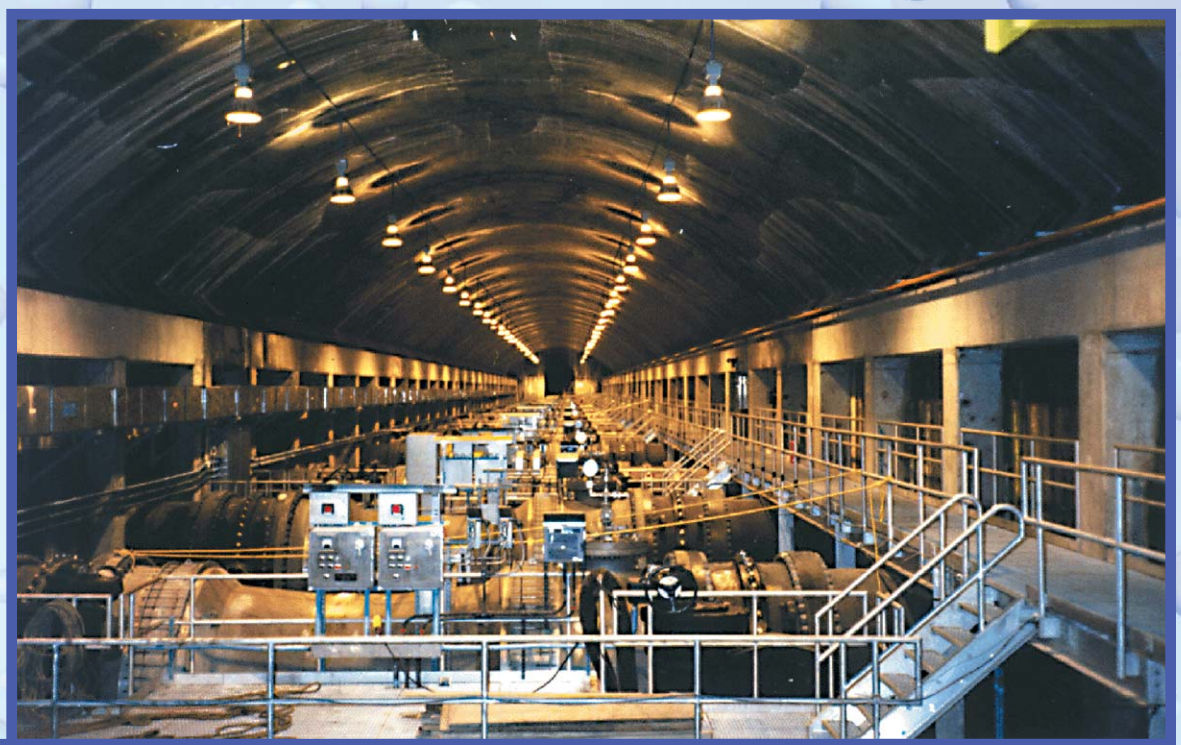
MORE INFO: www.nickelmagazine.org/0304/8.htm

- **The new Toyota Prius is the first to use a high-voltage (500V) hybrid drive system and a higher-performance nickel-metal hydride (NiMH) battery.**
- **It achieves a fuel efficiency of 35.5 kilometres per litre and is fully compliant with Japan's stringent emissions regulations.**
- **The sealed NiMH battery (top of page) is more compact and has a higher power density than Toyota's previous battery. It is charged by the engine via the generator at cruising speed, and by the motor during regenerative braking.**

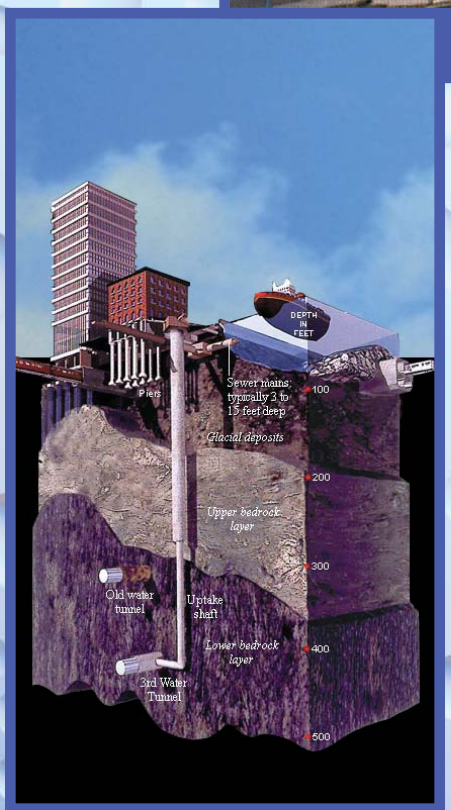
TOYOTA PRIUS

Stainless Steel Valves

are the cornerstone of New York City's water distribution system



The Van Cortland Park valve control chamber houses thirty-two, 22-tonne valves. Every day, about 1.4 billion litres of water flow through each of these valves to the different boroughs of New York City.



Twenty riser shafts bring potable water to surface for distribution along tunnel No. 3 and each shaft contains four, stainless steel riser valves.

New York City has a huge thirst for water, with projects for supplying that water dating back to 1837. Its most recent endeavour, a US$6-billion mega -project known as Water Tunnel No. 3, began in 1970 and is due for completion in 2020. It is a huge user of nickel-containing stainless steel.

The New York City Department of the Environment, which manages the project, needed valves that would provide low- or no-maintenance service for 100 years under conditions of 100% relative humidity. Based on corrosion immersion tests run in the 1960's, S30403 and S31600 stainless steel offer the best corrosion-resistance, lowest maintenance and best life-cycle costs of any material suitable for carrying potable water.

"As we supply water to citizens of New York, we can't really afford to have these systems down. We have to design [the system to be] so strong and corrosion-resistant, that we can have controlled maintenance shutdowns. A major breakdown would be catastrophic and replacement costs are very high," says Jessy James, deputy chief group leader of the Mechanical/Electrical Section 1, Division of Wateworks Design.

Stainless steel owes its corrosion resistance and long service life to a thin chromium oxide film that forms in the presence of air or water, which replenishes itself if scratched. The very agitation, turbulence and high velocity of water that are so damaging to carbon steel are normally beneficial to the durability and performance of stainless steel, due to the presence of this oxide film.

Valves constructed entirely of stainless steel were first installed in the Tunnel No. 3 water distribution system in 1987 during Stage 1 of the project. Additional units were installed in 2003 during Stage 2. Kubota of Japan manufactured the stainless valves for Stage 1, which are 10-tonne units with a throat diameter of 1.22-metres (m). Voest-Alpine of Austria manufactured similar sized units that weigh 6.4 tonnes apiece. The stainless steel valves installed in Stage 2 were manufactured by Argentina-based Mendoza.

A bird's-eye view of the No. 3 Tunnel project shows 99 planned kilometres of the tunnel (see accompanying diagram, this page). It runs from the northern New York City line under the Bronx, the length of Manhattan Island, under the East River and the boroughs of Queens, Brooklyn and back under the river to Staten Island.

Tunnel No. 3 starts at about 90 metres below surface where it taps into tunnels bringing water from reservoirs north of the city. It descends to a depth of over 240 metres as it heads south. Along its length are more than 20 riser shafts that bring water to the surface for distribution. Each of these, 1.2-m-diameter shafts is lined with stainless steel plate, 5 millimetres (mm) in thickness.

A typical riser shaft configuration has four, 1.2-m riser valves in each distribution chamber. A total of 20 stainless steel riser valves and 34 stainless steel distribution valves will be installed by 2020, according to James.

Although every riser shaft has a valve chamber, the Van Cortland Park valve control chamber, located under the Bronx, is unusual for its size, function and enormous valves. Put into service in 1998, it lies 60 metres below surface and measures 37 metres long by 18 metres wide.

Seventeen pipelines route water to different city boroughs. The water can be reversed through each pipeline, and each is fitted with an upstream and a downstream quarter turn butterfly valve. Each of the 32 valves weighs 22 tonnes, is 2.82-m high and about 5,080 mm long, with 2.44-m-diameter throats. Also, each has a contracted throughput of 1.4 billion litres per day, with an emergency capacity of 6.0 billion litres per day.

The valve bodies in this case are cast and machined carbon steel, though the closure members are made of stainless steel S30403. The closure members consist of a disc, 17.8 mm in thickness and 2.44-m in diameter, which pivots on a solid stainless steel shaft.

The valves were manufactured by Kubota, of Osaka Japan, in 1975, and the selection of materials was based on the results of corrosion immersion tests in New York State's Roundout Reservoir. These tests were designed to determine which alloys could provide an anticipated life service of 100 years. A number of alloys, including aluminum and manganese bronze alloys, brasses, bronzes and copper-nickels, were immersed in water for 10-13 years. Only the stainless steel samples and some nickel base alloys performed with virtually no corrosion, with stainless steel offering the most cost effective selection.

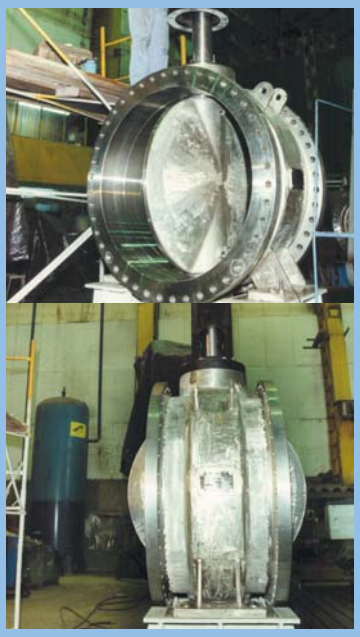
The new, stainless valves in Tunnel No. 3 are spectacular examples of the application of stainless steel in potable water applications.

The Van Cortland Park valve chamber's 17 venturi water meters, measuring more than 4.6 metres long with 183-mm throats and a maximum inside diameter of 2.44-m, are also made entirely of S30403, as are all of the accessories, rods and bolts that hold them together. Other riser shafts have 914-mm valves with carbon steel bodies.

No. 3 Tunnel runs from the northern New York City line under the Bronx, the length of Manhattan Island, under the East River and the boroughs of Queens, Brooklyn and back under the river to Staten Island.

The No. 3 Tunnel, with its stainless steel valves, is expected to help distribute water throughout New York City for at least the next 100 years.

MORE INFO: www.nickelmagazine.org/0304/10.htm



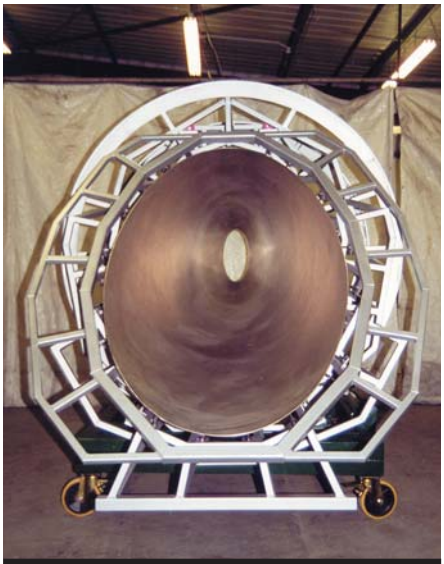
The motto for materials selection in the New York City water tunnel project is as follows: "The less metals other than stainless steel in the environment, the better," says Jessy James, deputy chief group leader of the Mechanical/Electrical Section 1, Division of Waterworks Design. Besides the valves, S30403 and S31603 stainless applications include riser valve, air relief and pump discharge piping, grating systems for each distribution chamber, handrails, lighting fixtures, valve actuators. A partial tally of these other stainless applications quickly exceeds 60 tonnes per riser, the number of which will exceed 20 by the 2020 project completion date.

NYC/DEP

The Quest for Lightness

Electroformed nickel molds are helping Airbus and Boeing create more fuel-efficient aircraft

Airplane manufacturers on both sides of the Atlantic are increasing the use of non-metallic composites, rather than alluminum alloys, to reduce the weight and therefore increase the fuel efficiency of their commercial aircraft. While this may be bad news for the aluminum industry, it is good news for the nickel industry.



ELECTROFORMED NICKEL tool-making techniques are ideal for creating shapes such as this BD100 tail cone.

The reason is that the molds (or "tools," as they are sometimes called) that are used to make the major carbon-fibre and other composite components are mostly made of either K93600 (or Invar™) or a thin layer of pure nickel deposited on a metal substrate in a process known as "electroforming." Each has its own unique application.

For example, Ex-Press Plastics (Process Equipment) Limited, in Norfolk, England, makes nickel electroformed tools that are used to fabricate the landing - gear doors of the Airbus A380. The company has also made an electroformed mold, 12.5 metres long, for the tail elevator of Boeing's 777. The company uses about eight tonnes of nickel per year.

Invar (which is 36% nickel and 64% iron) has a near-zero co-efficient of thermal expansion and is typically used to build tools from welded sheets or tooled blocks (for details, see the February 2003 issue of Nickel Magazine). However, electroformed nickel tools are created by depositing nickel on plastic "bathmasters," which are epoxy forms corresponding to the size and contours of an aircraft part.

Electroformed shell tools are lightweight and their consistent thickness enables them to heat evenly and quickly in an autoclave. "If you are running an autoclave at, say £60 an hour, it is important to know how long it takes to heat up the tool," explains Michael Shead, technical sales manager with Ex-Press Plastics. "You get more throughput in one of your more expensive resources. The (production) bottleneck is usually the autoclave. When you are busy, your autoclave can be running twenty-four hours a day, and your lay up department is not,"

In a process familiar to people in the electroplating business, the surface of a bathmaster is sprayed with a layer of silver nitrate just a few microns thick, then lowered in a nickel sulphamate solution. The silver acts as an initial conductive layer for the nickel to be deposited on. "Then the nickel itself becomes a conductor and you can increase the current loading on the bath mandrel," says Shead.

The finished thickness of the nickel is normally five millimetres, though, says Shead, "we aim for a deposit of four to six millimetres." Any thicker and the tool takes too long to heat up in the autoclave. Moreover, at that nominal thickness, the

AIRBUS

surface of the tool can be adjusted with a co-ordinate measure machine (CMM) to give the finished parts the proper dimensions.

Normally, a nickel electroformed tool will last for as long as a manufacturer needs to make components. If production rates are high, more than one tool is needed. In the case of the Airbus landing gear doors, four tools were ordered.

Shead says tool-making eliminates the vacuum leaks sometimes found in welded-up tools. Moreover, the tool surface is easier to adjust if components exhibit unacceptable "spring back" when removed from a tool.

"With Invar, if the component has spring-back, you can sometimes accept that, or you may have to re-machine the tool," Shead explains. "With electroformed nickel, you can adjust it to compensate for the spring-back of the carbon component. The shell is attached to a steel structure by studs that you can adjust to pull or push the nickel shell into position. We use a CMM five-axis head that feels its way around on the surface of the tool and compares its measurements with the CAD data." Technicians then adjust the studs to fine-tune the shell shape.

Designers use a compensation factor in the CAD file to offset differences in the co-efficient of thermal expansion between the shell tool and the composite material.

Invar finds application in deep-drawn tools, including, for example, a U-shaped box with almost 90° corners. "That would be the worst case for a electroformed tool," says Shead. "The tool would crush the part as it cools. An ideal shape for an electroformed tool is a J-shape, which has plenty of draft angle on the side and big radius on the bottom. The leading edge of wings and elevators and engine nacelles are good examples. The minimum radius (you can achieve) is the thickness of the shell; smaller, internal radii will reduce the shell thickness."

A shape such as an engine nacelle would challenge an Invar mold maker; however electroformed shell tools are well-suited for components with 3-D curves;

BOEING

MORE INFO: www.nickelmagazine.org/0304/12.htm

■ The ideal shape for an electroformed tool is a J-shape, such as this helicopter engine cover (top, left). ■ To give finished parts the proper dimensions, a co-ordinate measure machine (bottom, left) is used to compare the surface contours (in this case of a C17 flap track fairing tool) with the design values. ■ Inspectors measure the thickness of each tool, such as this aircraft flairing tool (top, right). ■ Side view (bottom, right) of the BD100 tail cone tool, also pictured on page 12 .

EXPRESS PROCESS EQUIPMENT

EU Proposes to Regulate Food-Contact Materials

In November 2003, the European Commission adopted a new proposal for a regulation on "materials and articles intended to come into contact with food". The Regulation is intended to replace the existing EU Directive 89/109/EEC. (Unlike a Directive, a Regulation becomes immediately enforceable throughout the EU once it has passed into EU law). It has now been passed to the Council and Parliament of the EU and is expected to go through its first reading during the first quarter of 2004.

Like the existing Directive, the Regulation enforces the first principle that no substance shall migrate from any material or article intended to come into contact with food in quantities that could endanger human health or affect the nature or quality of the food. Its provisions include:

- A "positive list" of authorised materials to be drawn up by the European Food Standards Agency and to be made available to the public.
- New materials, for which authorisation is sought, will be assessed through an application submitted via a member state.
- Labelling system to show compliance and to verify traceability of materials at all stages of manufacture, processing and distribution.
- Groups of substances (including metals and alloys) identified, which may be covered by "specific measures".

INCREASING HYGIENE standards favour stainless steel as a material for food contact surfaces. However, new regulations will lead to a need to obtain approval for all food contact materials.

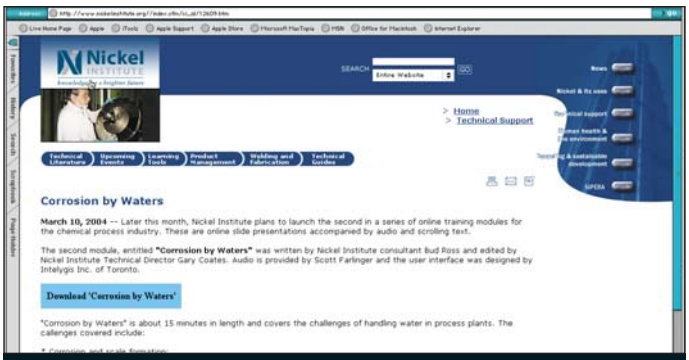
Online Presentation for Architects

The first in a series of online slide presentations on the topic of nickel-containing stainless steels in architecture, building and construction is now available at www.ivox.info

Designed for the British Stainless Steel Association (BSSA) by Geoff Stone, a consultant to the Nickel Institute, the presentation is available free to all users but is aimed specifically at U.K.-based architects and construction professionals who are seeking continuing professional development (CPD) credits.

The presentation consists of both slides and audio and provides guidelines for selecting and specifying stainless steel grades and finishes. Several architectural and construction projects serve as examples to illustrate various technical points.

Certified by the Construction CPD Certification Service, the presentation includes a short multiple choice quiz at its conclusion. After successfully completing the quiz, users can then download a CPD certificate.



THE NICKEL INSTITUTE has launched the second in a series of online training modules for the chemical process industry. "Corrosion by Waters" introduces the challenges of handling water in various processing plants with emphasis on corrosion and scale formation; macro-fouling; microbiological influenced corrosion; high chloride waters and crevice corrosion.
Visit: http://www.nickelinstitute.org//index.cfm/ci_id/12609.htm

UNS details

Details of the chemical compositions (in percent by weight) of the 5 nickel-containing alloys and stainless steels mentioned in this issue of *Nickel*.

Alloy	Al	B	C	Co	Cr	Cu	Fe	Mn	Mo	N	Ni	P	S	Si	V	W	Zr
S30400 P.5	-	-	0.08 max	-	18.00-20.00	-	-	2.00 max	-	-	8.00-10.50	0.045 max	0.30 max	1.00 max	-	-	-
S30403 P.10	-	-	0.03 max	-	18.00-20.00	-	-	2.00 max	-	-	8.00-12.00	0.045 max	0.030 max	1.00 max	-	-	-
S31600 P.4,5,10	-	-	0.08 max	-	16.00-18.00	-	-	2.00 max	2.00-3.00	-	10.00-14.00	0.045 max	0.030 max	1.00 max	-	-	-
N06601 P.7	1.0-1.7	-	0.1 max	-	21.0-25.0-	1.0 max	rem	1.0 max	-	-	58.0-63.0	-	0.015 max	0.50 max	-	-	-
K93600 P.12	--	-	-	-	-	-	64.0	-	-	-	36.0	-	-	-	-	-	-

NICKEL INSTITUTE

Renewable Energy from the Tides *continued from page 4*

"Corrosion at this stage is not a major issue. But should the idea prove viable, then we will be looking to some fairly serious materials work to be involved, because these things will be expected to have a working life (of 15 to 20 years) and they'll need to be built for it."

The *Sea Snail*'s tubular steel frame squats on the ocean bottom like an insect. Surrounding the central turbine are wing-shaped foils that create downward force as currents pass over them – much like the spoilers of a racing car.

"The faster the (tidal) stream flows, the more powerfully it's pushed onto the seabed," Owen explains.

The foils must flip as the tide reverses. The reversible hub that allows this to happen will be made out of stainless steel to ensure trouble-free operation. Designers have rejected the idea of an enclosed gearbox system. "From an engineering point of view, simplicity is always the preferred angle," he notes. "Therefore I would be inclined to the idea that we leave the mechanism open but make it out of materials that are corrosion resistant"

The foils, now made of glass fibre, may be re-engineered with a stainless steel skin, allowing seawater to be pumped in and out to maintain buoyancy. "That would obviously be a prime candidate for stainless steel. It creates a cavity that you can't get into to treat in any other way, so you have to make sure it can't corrode internally," Owen says. Corrosion-resistant steels are also likely to become the material of choice for turbines as they are perfected for undersea use, he adds.

Like MCT's prototype, Sea Snail is designed to be hoisted to the surface for maintenance. Tidal turbines will be installed where currents are strongest, and it's too dangerous to send down divers. And since the structures are partly or fully submerged, they will not clutter the landscape like offshore wind farms.

The potential for underwater turbines is vast. Owen's team foresees the installation of more than 100,000 units around the world over the next two decades, generating electricity from large-scale tidal farms or powering water purification or desalination plants.

"It taps into a huge, predictable and clean energy source," MCT's managing director, Martin Wright, says of the technology. "It has the potential to make a major contribution to future energy needs without causing pollution or any significant environmental harm."

MORE INFO: www.nickelmagazine.org/0304/4.htm

COMING EVENTS

Specialty Alloys

The 18th Stainless & Specialty Alloy Conference will be held in Pittsburgh, Pennsylvania, U.S.A. March 31 to April 1, 2004. Organized by American Metal Market, the conference will examine the reasons why stainless steel prices increased in 2003; new contracts between USW, AK Steel and Allegheny Technologies; the changing landscape of stainless producers in North America; and other important issues related to stainless steels and specialty alloys. Contact: Jeannie Lee, American Metal Market LLC, 1250 Broadway, 26th Floor, New York, NY 10001, U.S.A. Tel: 1 646 274 6213. Fax: 1 212 213 6619. E-mail: jlee@amm.com Web site: www.amm.com

NICKEL OUTLOOK 2004 is scheduled for May 20 and 21, 2004 at The St. Regis, in Shanghai, China. The conference will examine the outlook for China's economy; the changing pattern for nickel use in China; developments in the Chinese stainless steel industry; outlook for supply and demand; nickel resources, exploration and production in China; global markets and supply dynamics; and an outlook for the future demand for nickel. The conference is expected to attract: Chinese stainless steel companies, major corporate mining companies, nickel producers, finance and stock brokerage firms, Chinese government officials, freight/shipping companies, consultants and legal advisors, and engineering and contracting companies. Contact: Audrey Chen, IBC Asia (S) Pte. Ltd., No. 1 Grange Road, #08-02, Orchard Building, Singapore 239693. Tel: +65 6835 5137. Fax: +65 6733 5087. E-mail: audrey.chen@ibca-sia.com.sg Web site: www.ibc-asia.com

STAINLESS STEEL WORLD AMERICA 2004 CONFERENCE & EXPO is being held in Houston, Texas, U.S.A. on October 20-22, 2004. The focus of this three-day event will be corrosion-resistant alloys (CRAs). The conference will cover the broad range of CRAs that are being used in the oil & gas processing, power generation industries and architectural applications. Special emphasis will be on applications and practical field experiences. Managing costs and improving reliability is the common theme of the information that will be presented by end users, fabricators and producers. That information will be provided in the form of end-use case histories and shared experiences in the design, fabrication, specification and cost and supply management of CRAs. Special topics include: rouging, clad materials, weld overlays, risk-based inspection, failure analysis, welding, high-temperature applications and sourcing material in developing countries. Contact: Mr. Miel Bingen (Conference Secretary), Stainless Steel World, P.O. Box 396, NL-7200 AJ Zutphen, The Netherlands, Tel: +31 575 585 284. Fax: +31 575 585 284. E-mail: m.bingen@kci-world.com Web site: www.stainless-steel-world.net

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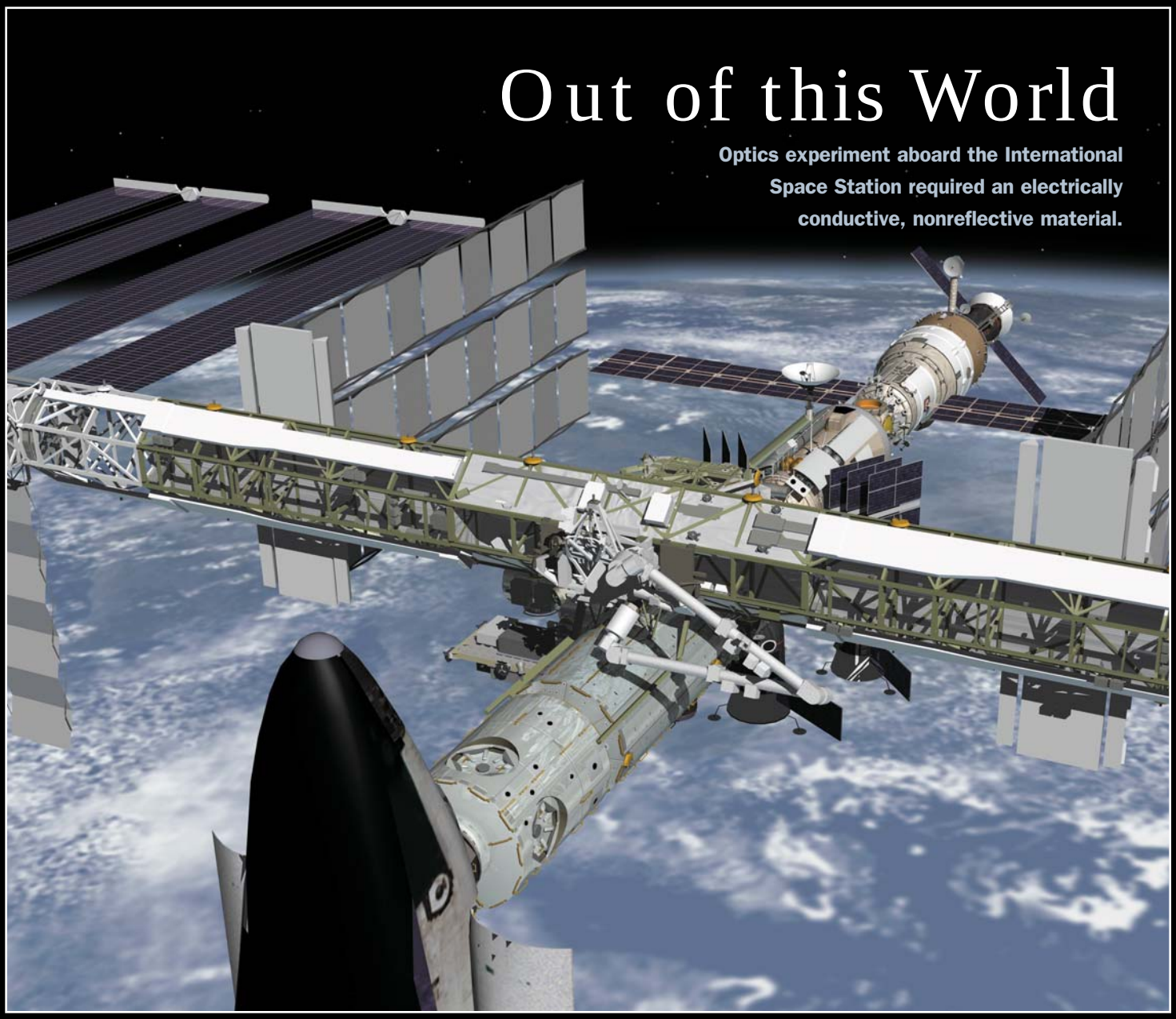
- **LATEST NEWS:** Visit the news pages of the Nickel Institute for the latest presentations and events of the publisher of Nickel Magazine. www.nickelinstitute.org/index.cfm/ci_id/12/la_id/1.htm
- **EUROPEAN NICKEL RISK ASSESSMENT:** Stay abreast of regulatory developments in Europe by visiting the web site of the European Nickel Group. www.nickelforum-eura.org
- **SCIENCE SUPPORT:** For all the latest published information on the environmental and human health science of nickel, visit the NiPERA web site: www.nipera.org

Out of this World

Optics experiment aboard the International Space Station required an electrically conductive, nonreflective material.



NASA/INTERNATIONAL SPACE STATION

The specs for the International Space Station include a work surface for scientists conducting optical experiments. Although the designers of the optics bench knew what they needed, a material that would meet all of their challenges seemed – literally – to be out of this world. "They wanted to make sure that no stray light was going to shine into their instruments," recalls Michael Feldstein, president of Trenton, N.J.-based Surface Technology, Inc. "They also wanted to make sure, as they slide the different pieces of equipment around in grooves and then clamp them down in different locations, that they weren't going to wear into the coating. And the last thing is, it had to be electrically conductive so that they can ground it, so that there wouldn't be any stray charge that could harm their equipment."NASA's engineers were surprised to discover that a stock coating could meet their demanding specifications. "They thought they were going to have to reinvent the wheel somehow," Feldstein notes.The solution turned out to be an aluminum bench clad in an electroless nickel coating that Surface Technology has been producing for two decades. NiPlate 700® incorporates ultra-fine silicon carbide particles that create an exceptionally hard, wear-resistant surface that conducts electricity, and, as it turns out, its matte-grey finish absorbs light. NiPlate 700 is part of a family of nickel-based coatings that Surface Technology has developed since it was founded in 1973. The company is the world's leading producer of composite electroless nickel coatings, holding more than 90 patents on its processes for bonding nickel and particles of diamond, silicon carbide, aluminum oxide and other materials into durable, high-performance finishes.

MORE INFO: www.nickelmagazine.org/0304/16.htm