NICKEL MAGAZINE

THE MAGAZINE DEVOTED TO NICKEL AND ITS APPLICATIONS

NICKEL, VOL. 34, NO. 1, 2019

Nickel: the great enabler

An engineer's guide to nickel steel

Garrison Crossing: stainless steel connecting communities

Longer-lasting batteries for Formula E

BOUYGUES TRAVAUX PUBLICS GROUP

CASE STUDY 15
MONACO EXPANSION PROJECT

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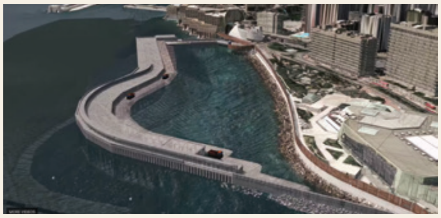
More than 4,000 tonnes of stainless steel rebar was used to construct the caissons and their floating construction dock.



BOUYGUES TRAVAUX PUBLICS GROUP

The second smallest country in the world and the most densely populated sovereign state, Monaco is immersed in an ambitious, eco-minded offshore extension project, a $2.3 billion six-hectare expansion of the city into the sea.

Developed by French construction company Bouygues Travaux Publics, construction of the maritime infrastructure is currently in progress with the submerged portion due to be completed by 2020. Anse du Portier (or Portier Cove as it is known in English), has been designed to fit naturally into the coastal landscape and conform to the flow of water near the coast.

The seabed will be dredged and filled with quarried rocks to support a seawall consisting of 18 concrete-filled chambers called caissons. The caissons, 30 m in length and 24 m in height with a unit weight of 10,000 tonnes, will be towed by ship to Monaco from Marseille.

The French-Spanish company SENDIN has used more than 4,000 tonnes of stainless steel rebar to construct the enormous caissons at their floating construction dock at the port of Marseille. Chosen for high resistance to corrosion against seawater chlorides, durability and avoiding future costly maintenance, stainless steel grade Type 2304 (UNS S32304) duplex was used with diameters between 12 and 40 mm, supplied by Roldan-Acerinox group.

Ultimately the new district, Anse du Portier, expected to be completed by 2025, will house up to 1,000 residents in apartments and villas as well as feature a landscaped park, a seafront promenade and a marina. Ni

EDITORIAL: **'THE ENABLER'** NICKEL MAKING LIFE AND THINGS POSSIBLE

Nickel rarely plays solo roles but, in its various forms, is spectacular in supporting parts. Sometimes prominent, sometimes subtle but always enabling technologies, processes and products to shine.

BRUCE WOOD, USDA-ARS, BYRON, GA

The healthy growth of one branch contrasts sharply with foliage that did not receive supplemental nickel.

The roles are 'all natural'. Everything nickel can do lies with its innate characteristics, including its little-known role as a micronutrient.

The essentiality of nickel is not common knowledge, nor is the fact that there are crop-specific applications of nickel-containing fertiliser. Likewise, nickel metal hydride and nickel cadmium batteries have been overshadowed in the public mind by 'lithium'. Poorly understood is that nickel is central to the revolutionary success of the dominant lithium chemistries in modern energy storage.

Another small and invisible example is the heat-resistant, sound-reducing nickel superalloy foam insulation for jet engines that could reduce the noise footprint of aircraft, making life near airports more livable.

Even the ubiquitous nickel-containing stainless steels are finding new applications, enabling machinery and processes to work more efficiently for longer.

That said, we have chosen in this issue to highlight all those nickel-containing alloy steels that aren't 'stainless steel'. Collectively, they are vital to thousands of engineering solutions and their distinguishing characteristics and examples of their various applications are shown.

Nickel plays many roles. Strong and ductile. Conducting and magnetic…or not. High temperature or low…or both. In solid, solution or alloy forms. And essential to life. Stars come and go but the many talents and roles of 'The Enabler' continue.

Clare Richardson
Editor, *Nickel* Magazine

Cryogenic applications such as LNG storage and shipping use steel containing 9% nickel.

NICKEL NOTABLES

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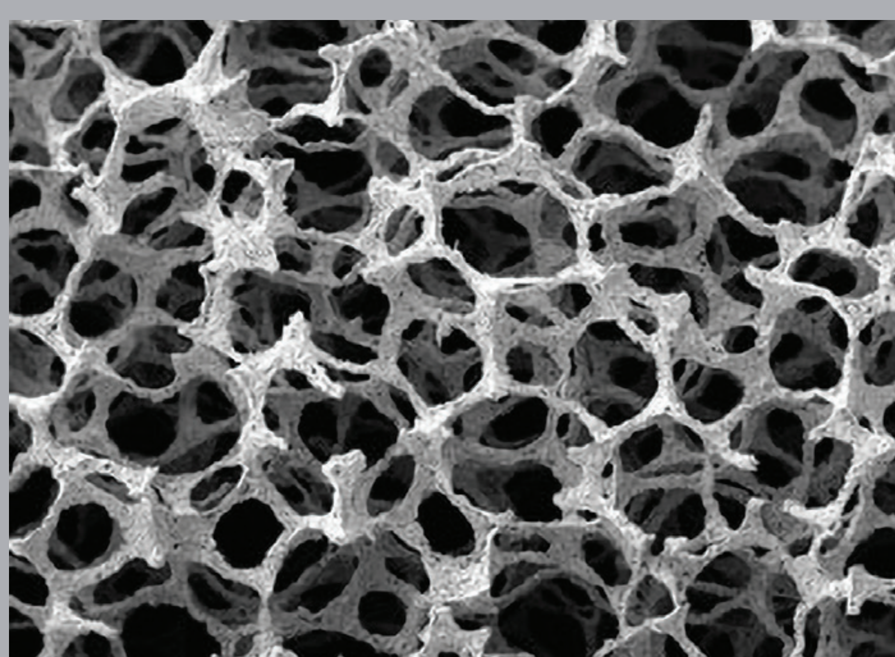
Erratum: Vol 33/No.3, 2018 Figure1, p10 corrected and available online

Quiet please

A new superalloy foam has been developed to reduce the roar of aircraft engines. A team at A*STAR has shown how regular polymer foams can be used as a template to create heat-resistant, sound-suppressing superalloy metallic foams. The researchers coated a polymer foam with a slurry of the nickel-based superalloy, then burnt off the polymer to leave behind an open-cell metallic foam with the same structure as the original polymer. Testing the acoustic properties of these metallic foams, they found the smaller the pores, the longer and more difficult the sound wave's path will be through the material, and the more time the material has to damp sound energy by converting it to heat — a phenomenon known as the thermo-viscous effect.



NISSAN'S REBORN LIGHT PROJECT

A light idea

In the small Japanese town of Namie, near Fukushima, car manufacturer Nissan and its affiliate, 4R Energy Corporation, are turning used electric car batteries into solar powered street lamps. They have come up with an innovative way to recycle electric vehicle batteries rich in nickel, manganese, cobalt and lithium. The project, titled 'The Reborn Light,' provides public lighting for residents as part of recovery efforts in the region devastated by the 2011 earthquake and tsunami. This new type of outdoor lighting is powered by a combination of solar panels and used batteries from the Nissan LEAF electric car. As part of the town's revitalisation, these stunningly designed standalone street lamps supply electricity to areas that are not connected to the main grid.

THOMASCOUNTYAG.COM

A little nickel grows a long way

It's a solution that has proven to be even more important as weather patterns change. In the southern United States, a prominent area for pecan trees, cooler spring temperatures and delays in warming are leading to the appearance of more mouse ear on developing foliage. Discovered to be the result of a nickel deficiency, mouse ear symptoms include a rounded or blunt leaflet tip, smaller leaves and leaflets, stunted tree organs, poorly developed root systems, delayed bud break, and necrosis of leaflet tips. Cooler soil limits absorption of available nickel which is needed for healthy foliage. The good news? Pecans don't need a lot of nickel and the problem can be prevented by monitoring the soil temperatures each year and treating with foliar applications of nickel when necessary.

A long life on Mars

While NASA officially declared its Opportunity Mars rover dead on February 13, 2019, it will be remembered for its unexpected longevity in harsh conditions. Deployed in 2004 and known as Oppy, it conducted measurements for 14 years. Powered by solar panels, Li-ion batteries stored excess energy to help with periods of peak power demand. The chemistry didn't change much in the early years because of Opportunity's ongoing success. The nickel-cobalt oxide (NCO) Li-ion chemistry of Oppy was up-graded to nickel-cobalt-aluminum (NCA) for the InSight mission launched in November 2018. The NCA chemistry provides improved performance.

NASA/JPL/CORNELL UNIVERSITY

GARRISON CROSSING: STAINLESS STEEL CONNECTING COMMUNITIES

PEDELTA, AERIAL VIEW RENDER

While other pedestrian bridges in North America have used stainless steel for part of their structures, and many highway bridges use stainless steel reinforcing bar in concrete, Garrison Crossing as a pair of all-stainless steel bridges is a first. Nickel-containing Type 2205 duplex stainless steel was selected for its high corrosion resistance against deicing salts.

Located just west of the main downtown area of Toronto, Canada, the 17.4 hectare Fort York historic area is an oasis of calm in a vibrant city. It dates from 1793, when the small town was known as York, and served as a defence for the harbour being manned by a garrison of soldiers. While the site today is a major tourist attraction, the green space known as Garrison Commons is very popular with city residents. However, access to the site for pedestrians and cyclists was by a busy road bridge, which crossed two major railway lines.

A competition was held for two pedestrian/cycling bridges, now known as Garrison Crossing, with the winning consortium led by Dufferin Construction. Pedelta Structural Engineers, an innovative international engineering firm, came up with a North American first – all stainless steel bridges. A duplex alloy, Type 2205 (UNS S32205) was chosen for not only its high strength and other structural properties needed in cold weather climates, but also for its high corrosion resistance against deicing salts. It will not need to be painted over its long lifetime and will have very low maintenance costs. Juan Sobrino, the president of Pedelta and lead designer for this project explained, "I have used stainless steel in many bridges in Europe, so I was very familiar with how it should be used structurally for the Garrison Crossing project." There were several challenges to overcome. There is no North American bridge code that references stainless steels, so authorities had to be convinced that the design was safe yet cost-effective. There had to be a merging of ideas and a great degree of coordination between all the partners. AISC (American Institute of Steel Construction) issued Design Guidelines for Structural Stainless Steel in 2013, and there is a European code that gave further guidance.

The fabrication of the bridges was, of course, a very critical element, and the job was awarded to a local firm, Mariani Metal Fabricators. Mariani had done some spectacular stainless steel work in the past, including the Air Force Memorial located just outside Washington D.C. Although they had previously fabricated duplex stainless steel, this was their largest duplex job, requiring about 350 tonnes of Type 2205. According to Vince Mariani,

president and founder of the company, "we were aware of the challenges going into the job, including special thickness and flatness tolerances of the plate, cleanliness in the shop and on-site, and especially on the special welding requirements." The surface finish of the steel is critical, so all parts were glass bead blasted. Even the handrails are in Type 2205.

The bridges are now in place, and the finishing touches being made. These are not only bridges, but a way of connecting communities together in a sustainable, environmentally-friendly and long-lasting way. Ni

Left: artist's impression of the completed bridges

Above: one of the bridges being fabricated at Mariani Metal Fabricators

Below: installed bridge before finishing with handrails

STRONG, HARD AND TOUGH
THE MANY WAYS NICKEL-CONTAINING ALLOY STEELS DELIVER

Hardenable low alloy steel is used for crank shafts, gears, and aircraft landing gear – all benefit from nickel content.

Tool steel – air-hardened steel shear blade

MILWAUKEESHEARBLADE

Most nickel production is destined for stainless steel. But a significant 8% is used in the production of alloy steels which are needed to deliver specific characteristics for specialised and often critical applications.

Alloy steels include a wide variety of iron-based materials. Nickel content ranges from very low, ~0.3% in some alloy steels, and up to as much as 20% in maraging steels. Each alloy is designed for some combination of greater strength, hardness, wear resistance or toughness than plain-carbon steels. They are typically used in equipment that delivers power, forms and cuts metal, or are used at low temperatures where carbon steels lack adequate toughness. For simplicity, alloy steels can be divided into several types, with specific properties for specific end uses. Nickel alloy steels are essential in the construction of tools and machinery that enable industry to make other tools and machinery. *See table page 9.*

Hardenable low alloy steel

These steels constitute a category of ferrous materials that exhibit mechanical properties superior to plain carbon steels. This is achieved by the addition of alloying elements such as nickel, chromium, and molybdenum, followed by a quench (rapid cooling) and temper heat treatment. These elements, when dissolved in austenite prior to quenching, increase hardenability. Nickel complements the hardening effect of chromium and molybdenum and is important in providing toughness to the hard-martensitic microstructure that results from the quench and temper heat treatment. *See table below.*

Comparing typical mechanical values for AISI 4340 in the annealed and quench and tempered condition to AISI 1045 carbon steel

75 MM (3") DIA ROUND BAR	YIELD STRENGTH MPa (ksi)	TENSILE STRENGTH MPa (ksi)	% ELONGATION
AISI 4340 annealed	588 (86)	752 (110)	21
AISI 4340 ASTM A434 class BD	847 (124)	963 (141)	18
AISI 1045 normalised	410 (60)	629 (92)	22

Tool steel

Tool steel is a term applied to a variety of high-hardness, abrasion-resistant steels used for applications, such as dies (stamping or extrusion), cutting or shearing, mould making, or impact applications like hammers (personal or industrial). Their heat treatment is similar to hardenable low alloy steels.

Air-hardened tool steels reduce distortion caused by the rapid water quenching and they possess a balance of wear resistance and toughness.

Plastic mould tool steels are low carbon steels that are shaped and then carburised, hardened and then tempered to a high surface hardness, which makes them ideal for injection moulds and die-casting dies.

High strength low alloy (weathering steel)

The finer grain structure of these steels results in increased strength compared to plain carbon steels. This finer grain is achieved by influencing transformation temperatures so

Maraging steel with 18% nickel content possesses the impact-fatigue strength required for aircraft landing gear.

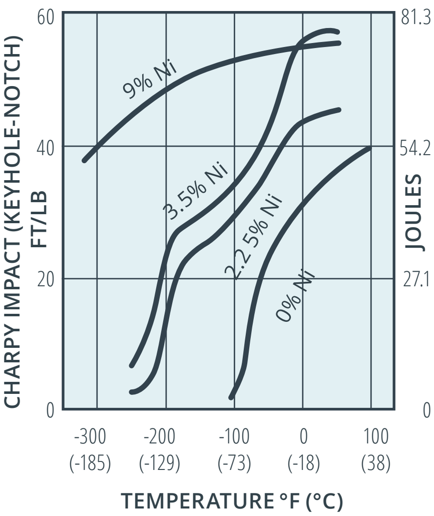
Typical chemical composition of some notable nickel-containing alloy steels.

STEEL TYPE	GRADE (UNS)	C	Ni	Cr	Fe	OTHER	APPLICATIONS
Hardenable low alloy	AISI 4340 (G43400)	0.4	1.8	0.8	bal	Mo	Transmission gears, shafts and aircraft landing gear
	AISI 4320H (H43200)	0.2	1.8	0.5	bal	Mo	Gears and pinions that are surface-hardened for wear resistance but possess a tough core
	AR450	0.26	0.70	1.0	bal	Mo	Abrasion-resistant plate for chutes, dump liners, grates, ballistic plates
Tool steel - Air-hardened	A9 (T30109)	0.5	1.5	5.0	bal	Mo, V	Drawing and forming dies, shear blades
Tool steel - Plastic mould	P6 (T51606)	0.1	3.5	1.5	bal		Zinc die casting and plastic injection moulding dies
High strength low alloy (HSLA) “weathering steel”	A588 Gr C (K11538)	0.1	0.35	0.5	bal	Cr, Cu, V	Provide higher strength to weight ratio than plain carbon steel and greater atmospheric corrosion resistance for use in bridge construction
Nickel steel	9% Nickel steel (K81340)	0.13	9.0	-	bal		Cryogenic applications such LNG storage
Maraging steel	Maraging 300 (K93120)	0.03	18.5	-	bal	Co, Mo, Al, Ti	Rocket motor casings, airframes, power shafts, aircraft landing gear, injection moulds, dies

The desirable properties of maraging steels can be summarised as:

- *Ultra-high strength at room temperature*
- *Simple heat treatment, resulting in minimum distortion*
- *Superior fracture toughness compared to quenched and tempered steel of similar strength level*
- *Easily fabricated with good weldability*

Figure 1: Effect of nickel on impact toughness of normalised and tempered half inch plates of low carbon steel



that the conversion of austenite to ferrite and pearlite occurs at a lower temperature during air cooling. At the low carbon levels typical of HSLA steels, elements such as silicon, copper, nickel, and phosphorus are particularly effective for producing fine pearlite.

The addition of chromium, copper and nickel produce a stable rust layer that adheres to the base metal and is much less porous than the rust layer that forms on ordinary structural steel. The result is a much lower corrosion rate allowing these steels to be utilised uncoated.

The table below shows the difference in mechanical properties for ASTM A36 carbon structural steel and ASTM A588 Grade C high-strength low-alloy structural steel.

Nickel steel

Ferritic steels with high nickel content, typically greater than 3%, find extensive use in applications involving exposure to temperatures from 0 °C to -196 °C. Such applications include storage tanks for liquefied hydrocarbon gases, as well as structures and machinery designed for use in cold regions. These steels utilise the effect of nickel content in reducing the impact transition temperature, thereby improving toughness at low temperatures.

In carbon and most low-alloy steels, as the temperature drops below 24 °C (75 °F), strength and hardness increase, while tensile ductility and toughness decrease. Nickel improves low-temperature toughness, as illustrated by the charpy impact results in *Figure 1*.

First applied in liquid oxygen containment vessels in 1952, 9% nickel steel has since mainly been used for the inner shell of LNG tanks. It is selected instead of austenitic stainless steels, due to the combination of high strength and reliable fracture toughness at very low temperatures down to -196 °C.

Maraging steel

Maraging steels are low carbon Fe-Ni alloys, containing ~18% nickel and additionally alloyed with cobalt, molybdenum, titanium and other elements. These alloys are quenched to martensite followed by a precipitation hardening heat treatment at 480-500 °C, which promotes precipitation of intermetallics such as Ni_3Mo and Ni_3Ti. These steels possess high fracture toughness, and their impact-fatigue strength indicates that they are useful for repeated impact loading situations, such as in electro-mechanical components. The relatively low heat treatment temperature results in much less distortion than the quenching of hardenable low alloy steels, making them desirable for long, thin parts.

Though the amount of nickel used in these alloy steels is less significant than in stainless steel production, their variety is extensive and industrially they are important enablers.

To help engineers and specifiers determine the best material for their application, the Nickel Institute provides free technical advice. www.nickelinstitute.org

The following table shows the difference in mechanical properties for ASTM A36 carbon structural steel and ASTM A588 grade C high-strength low-alloy structural steel.

GRADE	YIELD STRENGTH MPa (ksi) min	TENSILE STRENGTH MPa (ksi) min	% ELONGATION min
ASTM A36	250 (36)	400 (58)	23
ASTM A588 Gr C	345 (50)	485 (70)	21

GLOSSARY OF TERMS

Austenite is the atomic structure of steel that exists above 727 °C. It is a non-magnetic solid solution of iron and carbon.

Cementite is a compound of iron and carbon with the formula Fe_3C. As the carbon content of steel increases so does the amount of cementite and likewise the amount pearlite with an accompanying increase in strength. Increasing carbon content is the easiest means to increase mechanical strength and hardness, but with increasing strength there is an accompanying decrease in toughness.

Note: Reducing grain size (making it finer) also increases mechanical strength without an accompanying decrease in toughness.

Charpy impact is a standardised test which measures the amount of energy absorbed by a standard size metal coupon when it fractures.

Ferrite is the atomic structure of steel that exists below 727 °C. Ferrite has a lower carbon solubility than austenite and thus when steel is cooled below 727 °C, excess carbon is tied up as cementite and is layered with ferrite to form pearlite. Thus, at room temperature steel microstructure consists of pearlite islands in ferrite.

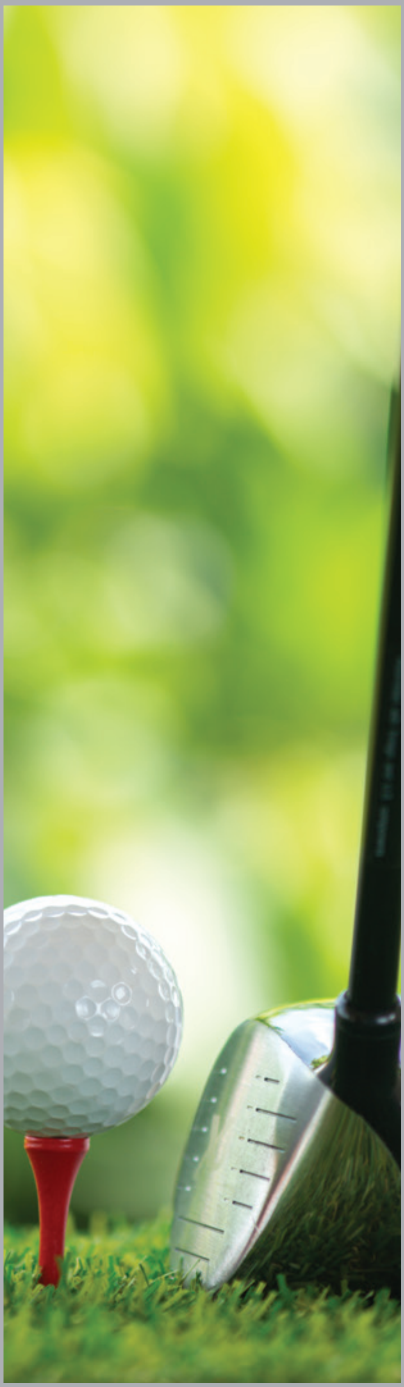
Hardenability is the ability of a steel to achieve a certain hardness at a given depth after rapid cooling (quenching).

Martensite is a magnetic structure of steel formed by quenching of austenite at such a high rate that carbon atoms do not have time to diffuse out of the crystal structure in large enough quantities to form cementite. As a result of the quenching, the austenite transforms into a highly strained structure that is supersaturated with carbon, which increases mechanical strength and hardness.

Pearlite is a lamellar structure composed of alternating layers of ferrite and cementite.

Precipitation hardening is a heat treatment technique used to increase the mechanical strength or hardness of malleable metals by promoting the formation (precipitation) of a dispersion of fine particles of metallic compounds (intermetallics) that stiffen the metal's crystal structure.

Toughness is the ability of a material to absorb energy and plastically deform, thus resisting fracturing when stressed.



Maraging steel is a high-performance material which can be found in the face or entire head of premium golf clubs.

DRUGS, VACCINES, AND STAINLESS STEELS
MORE NIMBLE AND DIVERSE PRODUCTION

GE HEALTHCARE

Above: GE Healthcare Xcellerex™ stirred-tank bioreactor

Allowing for quick startup and changeover between production campaigns, single-use technologies enable manufacturers to rapidly adapt to market needs.

The reduced need for open handling also reduces the risk of contamination.

Demand for biologics (drugs made from complex molecules manufactured using living micro-organisms, plants, or animal cells) are growing rapidly. For production capacities above 2,000-3,000 kg/year, nickel-containing stainless steels are making production of biologics economically viable. Below that production level, single-use technologies are cost effective.

The biologic route allows the production of more specific, niche drugs with increased potency. This has created increased variety but with smaller individual production runs, which in turn require more flexible production processes to respond more quickly to changes in demand.

In response, a new way of manufacturing has been developed with the use of single-use bioreactors. Bioreactors are vessels for growing organisms (yeast, bacteria, or animal cells) under controlled conditions. Usually made from Type 304L (UNS S30403) stainless steel (because the single-use liner inside the vessel is in product contact), they are increasingly used in biopharma industrial processes to produce biopharmaceuticals, vaccines, antibodies, cell and gene therapies and biosimilars.

In single-use bioreactors, the stainless-steel support vessels are lined with medical grade polyethylene for the production of a batch of a certain molecule. The linings are disposed of after each batch is produced. This means that the same stainless-steel production equipment can be used for the manufacturing of different molecules in small batches. In the past, to switch product, the production equipment had to be extensively cleaned or new equipment had to be built. In biotechnology, where the avoidance of contamination is of extreme importance, the cleaning process can take three to four days and use massive amounts of water. The removable liner eliminates or minimises the amount of cleaning of the equipment before starting another batch of a completely different compound. This increases the utilisation rate of the equipment and minimises downtime.

The future of single-use bioreactors

Looking forward, with the expected continued growth in demand for new drugs and chemicals, but smaller production volumes, the use of single-use bioreactors makes flexible manufacturing and smaller systems increasingly practical and appropriate. Because of the advantages that single-use offers in terms of reduced

GE HEALTHCARE

Left: GE Healthcare Xcellerex™ stirred-tank bioreactor

cleaning, reduced steam sterilisation, lowered utility costs, flexible facility design, and improved capital efficiency, single-use bioreactors also allow for more facilities to be built in emerging markets, allowing for distributed production.

The go-to grade

For all forms of drug manufacturing, the safety, purity and potency of the products is essential. Nickel-containing stainless steel is an important and cost-efficient material in drug manufacturing equipment, providing machinery and tubing surfaces that are smooth, easy to clean and sanitise and, if necessary, to decontaminate. Typically, in the pharmaceutical industry, the 'go-to' grades are stainless steel Type 316 (S31600) for the processing equipment in contact with the reactants, and stainless steel Type 304 (S30400) for the supporting structures. Both are straightforward to fabricate into the complex process machinery. Ni

FlexFactory leading the way

Biopharmaceuticals are protein-based medicines that are increasingly used to treat many diseases such as cancers, rheumatoid arthritis, diabetes and clotting disorders of the blood. Worldwide demand for these types of medicine is growing rapidly, driven by the world's ageing population and the move towards targeted, precision treatments.

In response, Parrish Galliher, Chief Technology Officer of Upstream Bioprocess at GE Healthcare's Life Sciences division, has pioneered the FlexFactory, based on modern single-use technologies, which gives producers rapid access to key biomanufacturing processes which can be tailored to fit any new or existing facilities. It also gives manufacturers the flexibility to modify individual processes as production needs change, or even develop a completely new production line within nine to twelve months."In the past you had to start building a plant five years ahead of time because that's how long it took to build, and five years is an eternity in biotech", explains Galliher. "Drugs come and go for all sorts of reasons, and half of the facilities were actually obsolete by the time they were completed; such is the rate of change in the industry."

Single-use bioreactors have several advantages, they:

- *reduce the need for costly and time-consuming cleaning and sterilisation validation procedures between batches,*
- *reduce solid waste,*
- *contribute to increased annual production capacity,*
- *lower capital and operating costs,*
- *increase speed and flexibility to set up the process allowing for quick startup and changeover between production campaigns,*
- *enable faster reaction to rapidly changing market needs, and*
- *minimise contamination risk because all components that contact the process material are enclosed within disposable units.*

THE RACE TO CHAMPION **LONGER-LASTING EV BATTERIES**

MCLAREN AUTOMOTIVE LIMITED

Formula E is grabbing the attention of the world's largest carmakers. Conceived in 2011 and launched in Beijing in September 2014, Formula E, all-electric championship audiences have rapidly risen to over 200 million, with speeds rising from 220 kph to 299 kph (137 mph to 186 mph) and range more than doubling.

Driving those increases is battery innovation

Every Formula E team must use the same battery technology, originally lithium-ion batteries with a capacity of 28 kWh. Williams was commissioned to build the first batteries, and now McLaren Applied Technologies is contracted to supply them, creating a new battery that has almost doubled the amount of usable energy to 54 kWh, so drivers can complete the entire race distance in one car. As with Williams, the chemical composition inside McLaren's Formula E batteries is a closely-guarded technical secret but one possibility is that McLaren is using a nickel-heavy design for enhanced energy density, with 8-1-1 chemistry, using eight parts nickel for every one part cobalt and manganese.

It may be years before the McLaren battery secret is known, so until then, it's about enjoying this exciting, innovation-inspiring sport. Ni

"Somehow McLaren seems to have achieved the impossible by upping the number of cells per car from 165 to 209 pushing the limits on weight, and near doubling of the energy density.

Many are curious as to how they have done it."

—Global Mining Observer

NEW PUBLICATIONS

The Nickel Institute has published two newly revised technical guides to assist in the effective use of nickel-containing materials.

The fully revised **Guidelines for the welded fabrication of nickel alloys for corrosion-resistant service (11012)** provides a useful guide for welders, materials engineers and design engineers. For the welder, it takes a "how to" approach useful for non-engineers. For the materials engineer, it is a useful reference that provides descriptions of the various types of nickel alloys and their metallurgical characteristics and discusses non-destructive inspections useful for ensuring fabrication quality. For the design engineer, it discusses design considerations to optimise the corrosion-performance of nickel alloys and the use of corrosion-resistant layers applied by weld overlay, sheet lining and clad plate.

Alloy selection for service in chlorine, hydrogen chloride and hydrochloric acid (10020), reviews the corrosive effect of chlorine, hydrogen chloride and hydrochloric acid with a range of materials including steels, stainless steels, nickel-base alloys, copper-base alloys, titanium, zirconium and tantalum under various conditions. This fully revised technical publication from the Nickel Institute provides a useful guide for materials engineers.

Available to download free from www.nickelinstitute.org

UNS DETAILS

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

UNS	Al	C	Co	Cr	Cu	Fe	Mn	Mo	N	Ni	P	S	Si	Ti	V
S30400 p. 13	-	0.03 max.	-	18.0-20.0	-	bal	2.00 max.	-	0.10 max	8.0-12.0	0.045 max	0.030 max	0.75 max	-	-
S30403 p. 12	-	0.08 max.	-	18.0-20.0	-	bal	2.00 max.	-	0.10 max	8.0-10.0	0.045 max	0.030 max	0.75 max	-	-
S31600 p. 13, 16	-	0.08 mas	-	16.0-18.0	-	bal	2.00 max.	-	0.10 max	10.0-14.0	0.045 max	0.030 max	0.75 max	-	-
S32304 p.2	-	0.03 max.	-	21.5-24.5	0.05-0.60	bal	2.50 max	0.05-0.60	0.05-0.20	3.0-5.5	0.040 max	0.030 max	1.00 max.	-	-
S32205 p. 6	-	0.030 max	-	22.0-23.0	-	bal	2.00 max	3.00-3.50	0.14-0.20	4.50-6.50	0.030 max	0.020 max.	1.00 max	-	-
G43400 p. 8	-	0.37-0.43	-	0.70-0.90	-	bal	0.60-0.80	0.20-0.30	-	1.65-2.00	0.035 max	0.040 max	0.15-0.30	-	-
H43200 p. 8	-	0.17-0.23	-	0.35-0.65	-	bal	0.40-0.70	0.20-0.30	-	1.55-2.00	0.035 max	0.040 max	0.15-0.30	-	-
T30109 p. 8	-	0.45-0.55	-	4.75-5.50	0.25 max	bal	0.5 max	1.30-1.80	-	1.25-1.75	0.03 max	0.03 max	0.95-1.15	-	0.80-1.40
T51606 p. 8	-	0.05-0.15	-	1.25-1.75	0.25 max	bal	0.35-0.70	-	-	3.25-3.75	0.03 max	0.03 max	0.10-0.40	-	-
K11538 p. 8	-	0.15 max	-	0.30-0.50	0.20-0.50	bal	0.80-1.35	-	-	0.25-0.50	0.04 max	0.05 max	0.15-0.30	-	0.001-0.10
K81340 p. 8	-	0.13 max	-	-	-	bal	0.90 max	-	-	8.5-9.5	0.035 max	0.040 max	0.15-0.30	-	-
K93120 p. 8	0.05-0.15	0.03 max	8.5-9.5	0.5- max	0.5 max	bal	0.10 max	4.6-5.2	-	18.0-19.0	0.010 max	0.010 max	0.10 max	0.5-0.8	-

STORELGEN, THE MIGHTY MOOSE

Storelgen took six months to complete and was shipped in pieces from China.
He stands 50 cm taller than Canada's Mac the Moose.

Along route E3 in Norway, a majestic moose towers 10.3 m high and stretches 11.5 m long, making him the world's largest moose sculpture. The mammoth moose, known as "Storelgen" (The Big Moose or Elk), comes with his own humongous moose droppings scattered throughout the picnic area to the delight of weary travellers.

The site was chosen to give motorists a reason to stop and stretch their legs and as a reminder to watch for local wildlife. Over 1,000 moose were struck by vehicles in 2015 alone, before Storelgen was erected in October of that year.

Storelgen was created by Norwegian artist Linda Bakke in collaboration with the Norwegian Public Roads Administration and cost about US$236,000. The statue was fabricated in China using mirror-polished Type 316 (UNS S31600) stainless steel "to make the statue as durable and maintenance-free as possible", says the artist. "And it was also a goal to beat Canada's Mac the Moose and be the world largest moose sculpture – and the prettiest". Ni