



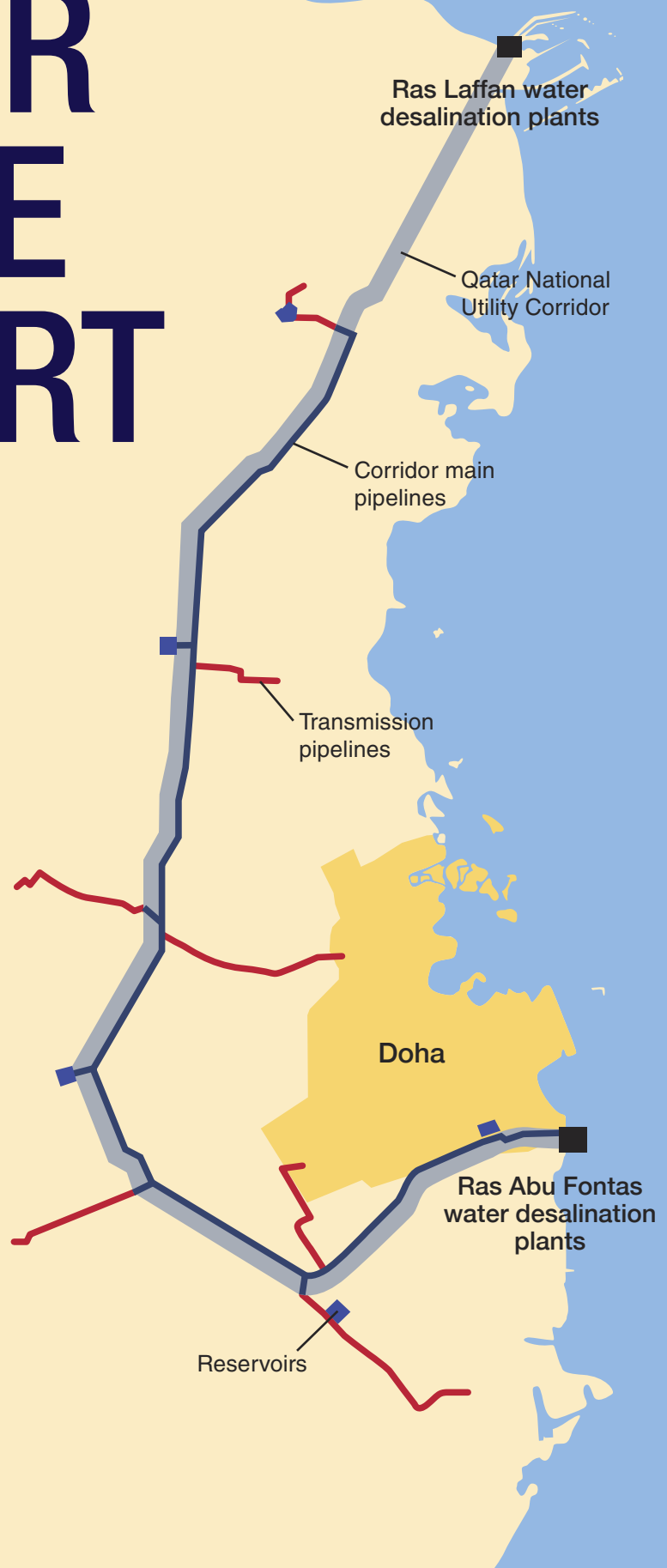
01/2020

# MOLY REVIEW

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# SUPPLYING WATER IN THE DESERT

Qatar, which the World Resource Institute lists as the world's most water-stressed country, is currently building a number of mega reservoirs to ensure a safe water supply for its growing population. Molybdenum-containing stainless steel dowel bars are helping to tackle this incredible challenge.





Maintaining a supply of clean drinking water in the desert is no easy feat. Increasing that supply for a growing population is even more challenging. Qatar is expected to see its population rise by nearly 20 percent over the next ten years. To keep pace with this growth, the country is building the world's largest reinforced concrete reservoirs.

## A growing thirst

Orchestrated by Qatar General Electricity and Water Corporation (KAHRAMAA), the ambitious “mega reservoir” project aims to address a huge increase in the demand for potable water. Qatar’s population is expected to increase from approximately 2.7 million to 3.3 million by 2030. The Qatari government is working diligently to build the infrastructure needed to accommodate this forthcoming population growth. To that end, the Qatar National Vision 2030 (QNV2030) development plan was launched in October 2008. Its stated objective is to “transform Qatar into an advanced society capable of achieving sustainable development” by 2030. The new series of mega reservoirs marks perhaps one of the most important facets of this development: securing a reliable water supply for the growing number of families, businesses, and tourists. Indeed, there will be a surge of visitors in 2022 when Qatar hosts the football World Cup in Doha.

Compounding the growing pains is the fact that Qatar lacks natural fresh water sources from lakes and rivers, and limited groundwater supplies are reserved for agricultural use. Therefore, Qatar’s potable water comes from two huge desalination plants. They convert saltwater from the ocean into high quality, potable water. The plants will be

connected to five reservoir sites via a 600-kilometer network of pipes with a diameter of up to 1.6 meters. The newly constructed reservoirs will ensure enough water is stored near population centers, where it is used, rather than where it is generated, thereby reducing overall pumping and energy required.

## Constructing mega reservoirs

The reservoir initiative is designed to extend potable water reserves in Qatar from two days to seven days. The project will roll out in two phases. The first phase aims to meet projected demands for water by 2026. This requires a storage capacity of about 8.7 million cubic meters, to be kept in the world’s 24 largest reservoirs at five different locations along the Qatar National Utility Corridor. The second phase of the project will provide seven days of water storage to meet expected demand in 2036. During phase two, 16 additional reservoirs will be added to the five reservoir sites. Ultimately, each of the five reservoir sites will include up to nine of the giant reservoirs.

The reservoirs will be interconnected, allowing water to flow from north to south and vice versa, so it can be delivered to the population centers in Eastern Qatar. Each of the 24 reservoirs in this first phase of the project covers an area of 300 meters by 150 meters, equivalent to nine football pitches, with towering walls reaching a height of 12 meters. It would take the water from more than 5,000 Olympic swimming pools to fill the reservoirs constructed in the first phase. Once the second phase of the project is completed, it will deliver a total storage capacity of approximately 14.4 million cubic meters.

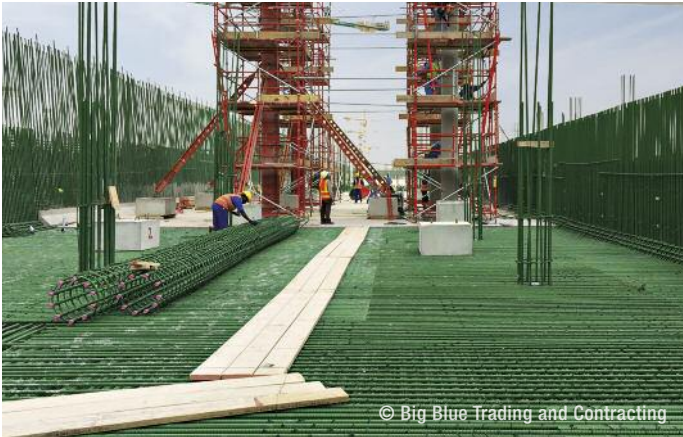
### The role of a dowel bar

A dowel bar is a smooth round bar that transfers load uniformly across joints in concrete construction, while still allowing the adjacent concrete slabs to expand and contract independently of one another.

Half of the dowel bar is firmly embedded into one concrete slab, while the other half is in a specially designed plastic sleeve in the adjoining concrete slab. Known as debonding, this allows the dowel bar to move freely in the sleeve with the expansion and contraction of the slabs. The sleeves consist of uPVC pipes that contain half the dowel bar, compressible filler, and an end cap. Once the finished dowel bars are in place, corrosion resistance is crucial as access for maintenance would be complex and costly.



© Big Blue Trading and Contracting



➤ The interior of one of the reservoirs under construction. A green Fusion Bonded Epoxy (FPE) coating protects the steel reinforcing bar against corrosion.

## An oasis with stainless steel

Molybdenum is a key contributor to the success of the reservoir project. Molybdenum-containing stainless steel dowel bars are used in the expansion joints of the walls and floors of the mega reservoirs. They allow the massive concrete slabs to expand and contract in a controlled fashion with changes in temperature and movements of lateral load, managing stress within the joints. The reservoirs are designed to operate for at least a century, so durability of all components is extremely important.

➤ One of the mega reservoirs at a distance. They will be filled with drinking water beginning in 2020.

## A few words from the project team

Dr. Steve Jones, commercial manager at Outokumpu, outlined some of the challenges faced when asked to supply the dowel bars for one of the reservoir sites. "We were approached with a demanding set of performance requirements. The dowel bars are exposed to a range of temperatures and corrosive environments. Molybdenum-containing stainless steel is a must for this type of application". The 2% molybdenum content in Type 316L stainless steel ensures good resistance to corrosion and a very long service life.

Waseem Ameen, Managing Director at Big Blue, the engineering company in charge, describes why Type 316L dowel bars were used. "We needed to be confident that we were using the appropriate grade of stainless steel that would give optimum performance and withstand the rigorous conditions within the challenging environment. The dowel bars will be required to perform without maintenance for many years to come, ensuring the mega reservoirs will supply water reliably to Qatar for the next century and beyond".

These massive mega reservoirs will support water security in the most water-stressed country in the world. Their construction is an engineering triumph, unparalleled anywhere. Molybdenum plays a crucial role in ensuring the longevity of the giant concrete tanks, which will supply Qatar with potable water for many decades to come. (MB)





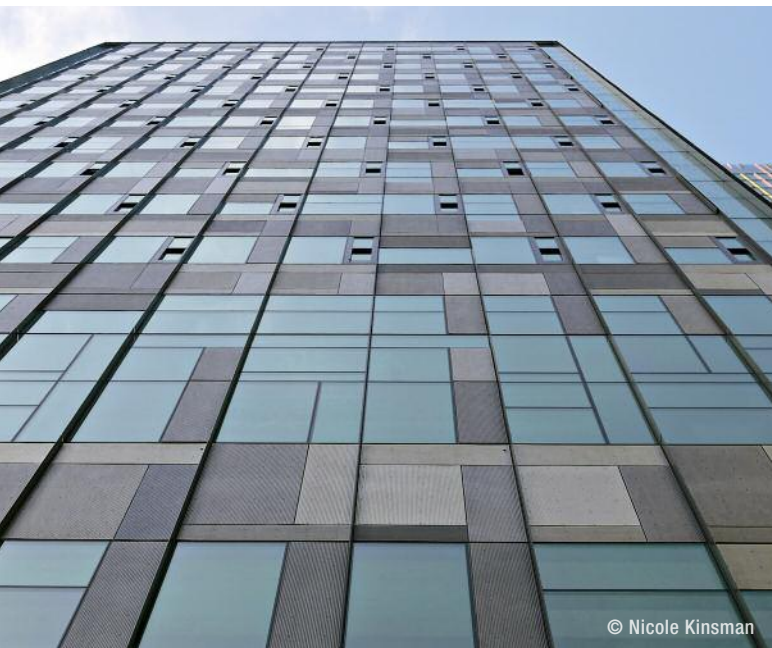


# ➤ Adding a splash of color

Who said skyscrapers must all be uniformly gray? Electrochemically colored stainless steel adds some whimsy to Seattle's new Doppler Building. The invigorating stripes of color serve as an antidote to the city's often cloudy skies. Below these stripes, a series of stainless steel sculptures at the building's base demonstrate another artistic application of this unique metal.

Rising 36 stories above Seattle's South Lake Union neighborhood is a sustainable beauty, created by NBBJ and adorned with Type 316 stainless steel. Even to 21st-century eyes, craning one's neck to assess the stature of a towering skyscraper remains a humbling prospect. And when looking up to see ribbons of color splicing the utilitarian grey, perhaps it is in admiration of the architecture of the future.





➤ A patchwork of champagne and brown stainless steel panels accent several of the Doppler's outer walls.

## Stainless, stylish, and sustainable

Perforated and electrochemically colored stainless steel “fins” separate the Doppler Building from the rest of the Seattle skyline. The building's glass reflects an ever-changing spectacle of color, caused by variations in light playing off the vertically oriented fins. This dance of light and color draws the eye upwards. Stainless steel is used in two places: in brown and champagne-colored panels on the side of the building, measuring 1.2 millimeters thick, and in protruding red and green fin panels, measuring 1.5 millimeters thick. The reflections of these colored panels off the glass transform the structure's 160-meter-high façade, designed by POHL, from office to artwork.

The Doppler Building houses Amazon's corporate headquarters, but its design also enhances the overall Seattle cityscape. Its campus includes a through-block plaza with food stalls and art work. The building received a U.S. Green Building Council LEED gold certification for its ecological design and use of sustainable materials, including stainless steel. This stainless steel has a high recycled content. At the end of service, a Yale study showed that about 92% is recycled into new stainless steel with no property loss. Stainless steel's durability and longevity are also frequently considered during USGBC LEED certification. When a Whole Building LCA analysis is conducted as part of the assessment, longevity, and maintenance must be evaluated. For example, if the colored panels were made of a shorter life material or one that required regular repainting, instead

**Electrochemical coloring** does not apply any pigments or other coloring agents to the surface that might impair the properties of stainless steel. Instead, it is achieved by thickening the passive film that naturally forms on clean stainless steel and gives it its corrosion resistance. Electrochemical coloring, patented in the 1970s, controls how the film forms and makes it more abrasion resistant and durable than chemical coloring alone. Thickening the passive film in this way does not change the color of the steel but instead filters out wavelengths of light, so it is also called light interference coloring.

of electrochemically colored stainless steel, replacement over a 65-year service life would be expected. But properly specified and maintained stainless steel panels should last the life of the building. Stainless steel offers the potential for significantly greater longevity over other materials, thereby potentially improving a building's USGBC LEED score.

## Withstanding an increasingly corrosive environment

With a 2% molybdenum content, Type 316 stainless steel offers protection against the corrosive elements present in Seattle's climate. The U.S. National Atmospheric Deposition Program (NADP), which collects data on the acid and salt deposited on surfaces from the air and precipitation, found that the chloride salt deposition levels documented in the Pacific Northwest are among the highest in North America. The accumulation of chloride salts on surfaces is made worse in this region by the frequency of both salt fog and very high salt content rain. Furthermore, air pollution originating in Asia is turning the once neutral-pH-rain highly acidic. While the Sound shelters Seattle and makes the environment less corrosive than areas directly on the coast, it is indeed a very corrosive environment, and the expected rise in rain acidity will only make the atmosphere more severe. Type 316 and more corrosion resistant stainless steels, like 2205 duplex stainless steel, will increasingly be needed to withstand this climate. Even with more acidic

rain and continuing assault from coastal salts, given proper maintenance, the stainless steel “rainbow” garnishing the Doppler’s façade is expected to retain its cheery color.

## Stainless steel as art

In the public plaza adjoining 6th and 7th avenues, visitors can admire sculptures created by local artist, Julie Speidel, also made with Type 316 stainless steel. The five-piece installation, called “Petros”, is a series of flat-sided, irregular polyhedrons. These beautiful, rock-like sculptures represent

unique rock formations left by a receding glacier in the area 14,000 years ago. The sleek, modern look of stainless steel contrasts with the form of ancient stones, creating a space outside of linear time at the foot of the skyscraper. Together, the ribbons of color above and metallic stones below underscore the artistic versatility of stainless steel.

Whether as sculpture or colored panel, stainless steel is a prominent visual feature at the Doppler Campus. Its corrosion resistance also helps to obtain the desired longevity of the building and its artwork in Seattle’s salty air. Visitors will enjoy the various, beautiful expressions of stainless steel present here for years to come. (KW)

➤ This stainless steel sculpture is part of the “Petros” collection of sculptures by Julie Speidel.



© Nicole Kinsman





# Making light of heavy vehicles

The drive to protect the planet for future generations is gathering momentum. Where possible, organizations are striving to reduce their environmental footprints. This is undoubtedly the case in the automotive industry, with initiatives like light-weighting and the development of electric vehicles. Molybdenum-containing steels enable a number of exciting improvements in efficiency, safety, and sustainability in heavy vehicles.



© iStockphoto.com/DarthArt





➤ Lighter trucks can reduce fuel consumption, and with that, air pollution.

Tens of millions of trucks drive enormous distances each year to deliver their loads. The movement of goods is a complicated, resource-intensive affair. Despite efforts in recent years to remove freight from the roads onto alternative modes of transport, such as trains or ships, trucks remain the backbone of the industry. These heavy, gas-guzzling vehicles deliver anything from building supplies, to clothes and groceries, to fuel and heavy industrial parts. Today's world would simply grind to a halt without the constant movement of freight on the roads. Finding ways to lessen the environmental impact of trucking is therefore essential for a more sustainable transport of goods and commodities. Specialized, molybdenum-containing steels are helping to make trucks and other vehicles lighter, and therefore, more fuel-efficient.

## Molybdenum – keeping things light

Molybdenum has been part of the steel structures of cars and light-weight vehicles for more than 30 years. Moreover, in recent years government agencies around the world, including the U.S. Department of Energy, have set specific targets for weight reductions in heavy trucks by 2050.

With this in mind, it is clear that molybdenum is set to play an even greater role in making trucks safer, more efficient, and more sustainable.

Such weight reduction targets can be achieved with many different materials. Carbon fiber composites, aluminum, glass fiber composites, advanced high-strength steels, as well as steel and cast-iron materials are all potential options. However, materials that are not traditionally used in the manufacturing of heavy trucks, such as carbon fiber and glass fiber composites, present significant technical challenges in terms of joining and forming. Aluminum is currently used in a limited capacity but presents a different set of technical difficulties. High-strength steels and cast-iron materials have many properties, including strength, weldability, and formability, that make them ideal for heavy vehicles. And with the current state-of-the-art manufacturing technology already in use, it is possible to incorporate these materials without having to revamp existing production facilities.

Performance criteria between trucks and cars are, of course, completely different. On average, trucks cover about 150,000 kilometers per year, and they have considerably more power and torque than cars. But the weight of the truck cab is surprisingly similar to that of a car – about 326 kilos – and uses many of the same materials.



Molybdenum-containing high-strength steels and press-hardened steels are used increasingly in both truck cabs and cars to reduce weight. More critically, new safety crash standards introduced in Europe to protect truck drivers called for improved truck designs. The use of high-strength steels provides the required levels of crashworthiness while reducing the overall weight, resulting in both a safer and greener truck.

## Proven performance in China

In a recent project to design new steels in China, using an improved 670 MPa strength steel reduced the weight of a truck’s trailer beam by 27%, when compared to the original 520 MPa steel. This reduction was possible due to the steel – which contained 0.2% molybdenum – being stronger and thinner than the original. In this case, the higher-strength steel was found to show the best performance to cost ratio for many major truck components. These new, lighter parts are either cost-neutral or even cheaper than those made of traditional steel. The result is a “win-win” situation that has tremendous potential for both the environment and manufacturers.

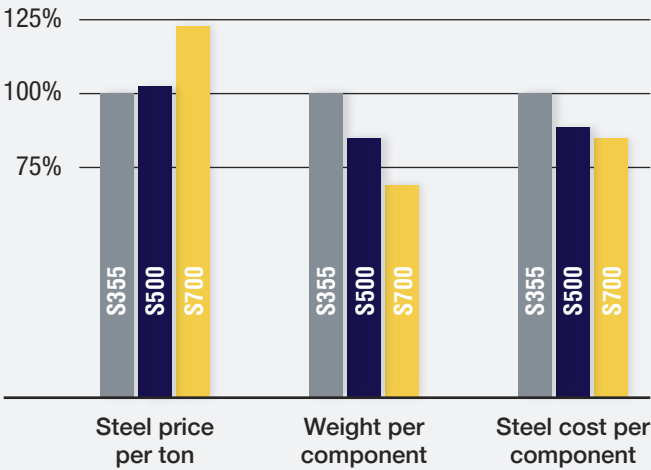


➤ Using a stronger steel means that the cross section of the trailer beams can be reduced, making the trailer lighter.

The heaviest part of the truck is the power train, which contains the drive axels. These are ordinarily made from a fairly low-strength steel (350 MPa), and weigh between 200 and 600 kilos. Current research projects in China are developing alloyed steels with increased strength. If these projects can realize the target strength of 550 MPa, it will result in a drive axel weight reduction of around 31%. The axel housings under development also allow for the use of electric engines to support the hybridization of trucks.



Economics of light-weighting with high-strength steel

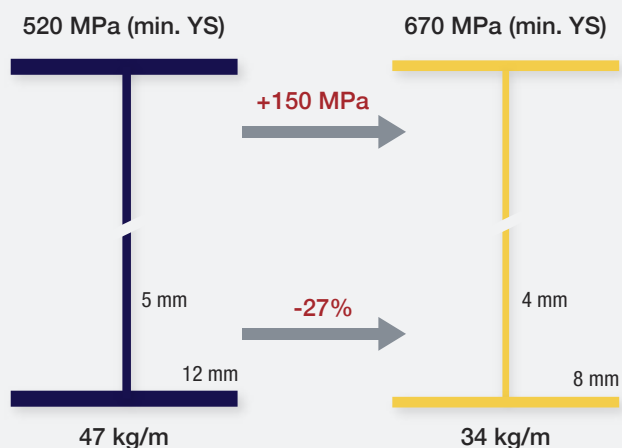






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Example of weight saving in a structural trailer beam (150 x 465 mm)

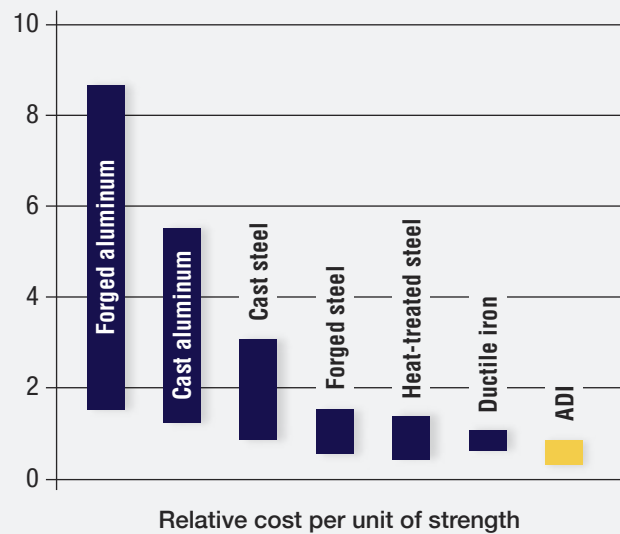
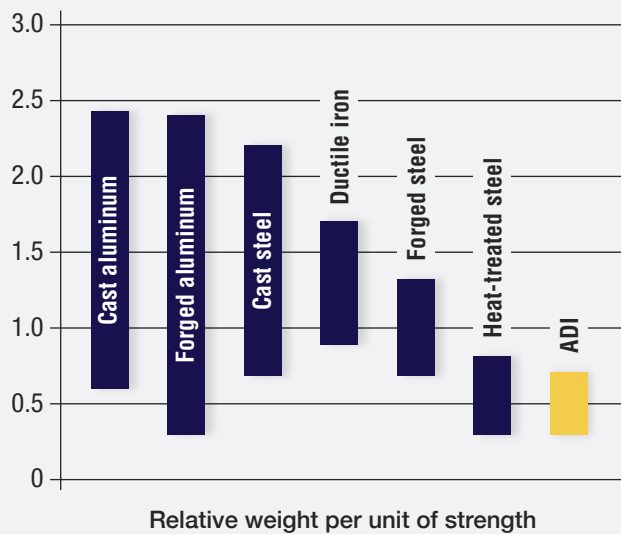


➤ Light-weighting truck components with stronger materials can make trucks lighter, allowing increased payload and improved operator profitability.

## Other applications in trucking

Trucks have many other heavy gauge parts that have to endure significant loads, shock, and wear. One example is the “fifth wheel”, where the trailer is hooked to the cab. Typically made from molybdenum-alloyed Austempered Ductile Cast Iron (ADI), it has a 10% lower density than steel, meaning it’s lighter than any steel alternative. ADI also has excellent noise damping capabilities and self-lubricating properties in dry contacts. ADI is not only used in the fifth wheel but also lends its light weight to other parts of the truck. For example, ADI wheel hubs, containing 0.3% molybdenum, are 20% lighter than comparable aluminum ones.

## ADI's competitive position vs. steel and aluminum



Molybdenum also plays a significant role in one of the vital safety features of a truck: the brakes. When applied, brakes create substantial amounts of heat. Therefore, they need to be made out of a material that has good thermal conductivity to ensure that the heat is lost quickly.

➤ Typical ductile iron truck components include wheel hubs and parts of the suspension system.



Grey cast-iron alloys are ideal metals for brake discs and drums. The addition of 0.2–0.4% molybdenum increases strength and thermal conductivity, while forming carbides to enhance wear resistance.

There is also an unyielding demand for greater engine efficiency. The U.S. Department of Energy has set stringent targets for reducing weight and increasing the efficiency of engines between now and 2050. This requires yet-to-be-developed irons and steels with higher strength specifically to support engine downsizing.

Current diesel engine efficiency is around 40%. In the future, up to 60% will be achievable, reaching similar efficiency levels as a hydrogen fuel cell. These increases in efficiency demand higher temperatures in the exhaust system and higher pressure in the cylinders. IMOA is working with Shanghai University's casting unit to develop grades of molybdenum-containing cast iron that can achieve the required results by optimizing heat conductivity, strength, and thermal fatigue resistance.

Research projects like this are an important part of ensuring trucking remains viable as a sustainable option for getting goods from A to B. It will take years, perhaps decades, and significant research and funding to achieve 60% engine efficiency. But work is ongoing, and progress is being made. One thing is clear: for millions of vehicles around the world, molybdenum's role is proving to be increasingly important. (S, HM)





# FASCINATING FASTENERS

The Large Hadron Collider at CERN in Switzerland is one of the world's biggest and most complex scientific instruments. By smashing subatomic particles at unimaginable force, the collider generates data that could help answer some of the fundamental questions of physics and explain life and death of the cosmos. Molybdenum is instrumental in carrying out these revolutionary experiments.

➤ The location of the LHC's underground track is indicated in red; a LHC dipole is modeled in the foreground.  
© 2009-2020 CERN





➤ Engineers test the electrical system of one of the LHC's super magnets.

More than a quarter of a million special-quality, high-strength Type 316L stainless steel fasteners are being used in an upgrade of the Large Hadron Collider (LHC), the world's largest particle accelerator. Located near Geneva, Switzerland, the LHC is a colossal structure designed to unearth secrets of the smallest known particles in the universe. It is a machine so powerful that at first, some feared it would produce a black hole capable of swallowing a chunk of the galaxy. Fortunately, the accelerator dutifully smashed protons and ions without any such incident, all while generating data for the study of particle physics. However, scientists want to increase the intensity of the accelerator's particle beams for forthcoming projects, and the LHC was due for routine maintenance. Hence, upgrade work on the accelerator commenced at the end of 2018.

This renovation is expected to take two years. In addition to performing system maintenance, the upgrade will allow

researchers to collect ten times more data than in the past. Part of this project includes replacing the fasteners that hold the accelerator's vacuum tubes and machinery together. These new fasteners will have to endure much for the sake of science, including temperature swings from -271 to 300 degrees Celsius. But their efforts will be well worth it, as these molybdenum-containing connections will help ensure that experimentation continues into the future.

## An extreme machine

The LHC first began operating in December of 2008 and is the latest addition to CERN's particle acceleration complex. It consists of a 27-kilometer long ring of superconducting magnets. Inside, two particle beams race around the track at nearly the speed of light, towards collision with one another, propelled by the superconducting magnets. Before they collide, the beams travel in opposite directions in two separate beam tubes maintained at ultrahigh vacuum. The superconducting magnets are chilled with liquid helium to below the temperature of outer space: -271.3 degrees Celsius. This extreme cooling is necessary so the magnets can remain in a constant, high-energy, superconducting state without resistance or loss of energy. To cope with these extreme conditions, the materials used in the collider must be among the most durable on earth.

By focusing the energy of a moving aircraft carrier into a beam less than a millimeter wide, the LHC splits protons and ions in the hopes of unearthing subatomic particles to study their properties. In 2012, the accelerator yielded the ground-breaking discovery of the Higgs Boson Particle. This find helped fill knowledge gaps in the Standard Model of Physics, a five-decade old theory that explains how mass comes to be in the universe. More than 2,000 papers have been published in the field of particle physics with data provided from the LHC. Of course, discoveries often lead to more questions. Scientists hope that by doubling the number of collisions per second, some of these new questions will be answered. With upgrades in place, the LHC is expected to produce over 15 million Higgs Boson particles per year, compared to three million in 2017. Increasing the number of Higgs Boson provides substantially more data and more opportunity to observe new phenomena.

## Upgrading the LHC

Shutting down and preparing the LHC for maintenance requires the collaboration of thousands of international scientists. To replace more than 20 of the superconducting magnets and other parts of the machine, teams have to install lifts to travel 100 meters underground. Just warming the unimaginably cold accelerator to room temperature took some four months and the removal of more than



100 tonnes of liquid helium. Needless to say, maintenance on the LHC is a titanic ordeal requiring the mobilization of countless resources. Therefore, high-strength parts with long service life, such as molybdenum-alloyed fasteners, are of the utmost necessity.

## Formidable fasteners

The fasteners used in the LHC upgrade have special requirements and differ significantly from standard Type 316L fasteners. They must be much stronger and have much lower magnetic permeability. Their minimum tensile strength is 1000 MPa, compared to 800 MPa, the highest strength level in the relevant ISO standard. Their yield strength is at least 900 MPa, compared to the standard's 600 MPa. The non-magnetic nature of these fasteners is critical to avoid disrupting the movement of particles during acceleration. To achieve this outstanding combination of properties, their producer, Bumax in Sweden, specifies a higher molybdenum content of 2.5 to 3%, compared to the typical 2 to 2.5%, among other things. By



➤ Close-up of various size fastener bolts, similar to the ones to be used in the LHC upgrade. © Bumax

**1 Billion:** number of collisions per second

**10 November 2008:** date of LHC's first ever particle beam

**26,695:** length in meters of the LHC superconducting ring

**Approx. 250,000:** number of fasteners that will be replaced during the latest upgrade

**2178:** number of daily staff required to keep LHC running

**600:** number in Gigawatts for average annual power consumption of LHC

**-271.3:** operating temperature within LHC magnet dipoles

**11,245:** number of circuits a particle makes around the superconducting ring each second

**4%:** estimated percentage of the universe that is known tangible matter

**96%:** estimated percentage of the universe made-up of little known particles

lowering the stainless steel's magnetic permeability, molybdenum plays a central role in making these fasteners virtually non-magnetic.

The fasteners, made of austenitic stainless steel, must be cold worked to achieve the tensile strength needed to withstand the intense temperatures and forces present in the LHC. However, during this strengthening cold working process, a portion of the non-magnetic austenitic microstructure of Type 316L stainless steel can transform into deformation martensite, which is, indeed, magnetic. These minute defects could derail the functionality of the accelerator by interfering with particle flow between the superconducting magnets. A higher molybdenum content helps to prevent this martensitic transformation. The result is an ultra-strong fastener that also will not influence magnetic forces present in the LHC.


The ability to ward off martensitic transformation is also essential to the structure of the collider itself: the 27.4 kilometer-long vacuum tubes that house the particle beams are therefore made of Type 316LN stainless steel. In this variation of Type 316 stainless

steel, the elevated nitrogen content provides higher strength and prevents martensite formation. Here too, without very low magnetic permeability even at cryogenic temperatures, the accelerator would not function properly. Special austenitic stainless steels are therefore widely used in other applications throughout the accelerator's design.

## Continuing the collision

In 2021, the Large Hadron Collider is expected to resume operation. Scientists from 29 organizations across 13 countries will begin the project that doubles the number of atomic collisions per second. With new, molybdenum-containing fasteners in place, the particles are free to smash themselves without magnetic interference. The strength of the fasteners means they can gladly endure the intensity of the upgraded particle beam. And perhaps something even more revolutionary will reveal itself, and molybdenum becomes a medium through which the mysteries of the universe are explained. (KW)





# > “Each autonomous, and yet together”

At the inauguration of the Nordic Embassies in Berlin in the autumn of 1999, Queen Margrethe II of Denmark formulated this motto for the future cooperation of the five Nordic countries. Twenty years later, this unique project is still making a statement about international friendship – and the lasting, low maintenance beauty of molybdenum-containing stainless steel.

© Martina Helzel



The Nordic Embassies are a complex of buildings where you can not only learn about collaboration between countries, but also see this concept expressed in architectural form. A green copper band, which has since become a famous landmark, encompasses the cluster of individually-designed embassy buildings. The supporting structure of this 15-meter high band is made of molybdenum-containing stainless steel, just one of its numerous applications at the Nordic Embassies.

## Both united and unique

After the fall of the Berlin Wall and the reunification of Western and Eastern Germany in 1989, it was decided to relocate the seat of government back to Berlin. The five Nordic countries – Denmark, Finland, Iceland, Norway, and Sweden – used this opportunity to realize the idea of a joint embassy complex. This unique cooperation was initiated not out of necessity, but rather out of a sense of common heritage, common languages, and shared values and convictions.

The overall concept of the site, designed by the Austrian-Finnish architects Berger and Parkkinen, perfectly captures the idea of a strong community. Arranged according to their location on the map, the embassy buildings are complemented by a shared cultural center and event venue called “Felleshus”. These six, uniform-height structures are built in such a way as to create the illusion of sections that have been carved out of a single block. Intersecting paths and shallow ponds representing the seas simultaneously divide and link the buildings.

Each embassy building is designed by architects from its respective country and has its distinctive identifying features. What unites the buildings is the consistent use of materials



➤ Aerial view of the embassy complex.

typical of the Nordic region like wood and natural stone, combined with glass and stainless steel. In this interplay of materials, stainless steel can show off all its versatile properties: an elegant appearance in plain, perforated façade panels, its corrosion resistance at almost invisible fixing points, and its strength in huge load bearing structures.

## Linked by stainless steel

Wrapped around the site and enclosing the six buildings is a curved, 226-meter long band consisting of louvers with around 4,000 prepatinated copper slats. Generous openings and different angles of inclination among these louvers offer light, air, and protection. These apertures also provide visual relationships between the outside and the inside of the embassy buildings.



➤ Street view of the copper band encircling the Nordic Embassies.





- Stainless steel is used in many components in this project: fasteners, drain pipes, anchoring for flagpoles, support profiles for the glass wall which separates the courtyard from the public spaces, and not least, in the perforated facade of the Danish embassy in the background.
- Copper slats and a stainless steel frame are a perfect combination: The materials have a similar coefficient of thermal expansion, avoiding stresses with temperature variations and the pairing does not suffer from galvanic corrosion.



The slats are fixed to a 15-meter high vertical support structure made of Type 316Ti stainless steel hollow-sections. A variety of reasons prompted the architects' material choice. In terms of functionality, the benefit is that copper and stainless steel do not suffer from galvanic corrosion and stainless steel is regarded as virtually maintenance-free. Additionally, a stainless steel frame proved to be only slightly more expensive up-front than construction in coated steel, which would have required regular recoating, a near-impossibility given that thousands of slats would have to be removed and reattached. Design considerations were the final deciding factor. The materials concept for the embassy complex called for the use of uncoated, unfinished surfaces, thereby allowing the natural properties of the individual materials to shine.

While other materials, especially wood, developed their natural patina over the years, the stainless steel retained its clean and bright appearance. Washed regularly once a year with plain water to remove any dirt, the stainless steel shows no traces of staining or corrosion. Even stainless steel elements like the mounts of the flagpoles or railings, which are close to the ground, have resisted de-icing salt exposure over the years thanks to the 2% molybdenum content of Type 316Ti.

Stainless steel complements the range of building materials used for the Nordic Embassies. Knowledge of the materials' properties was key to expressing the concept of "each autonomous, and yet together" in the design. The blend of strengths and weaknesses of each material become something greater than the sum of their parts, which also serves as a metaphor for the relations between the five nations. Although the buildings are highly-secured, the design creates a minimalistic and light atmosphere that feels inviting and relaxed – typical of the Nordic countries. The high copper band does not come across as an insurmountable wall but instead offers the entire complex an appropriate, urban presence in the heart of Berlin. At one end of this band, the Felleshus, which is open to the public, welcomes people to exhibitions, readings and other events related to the Nordic culture, or just to have a coffee in the bar and enjoy the Scandinavian design.

Overall, the Nordic Embassies' Type 316Ti stainless steel elements have performed beautifully during the 20 years since inauguration. The consistent use of stainless steel throughout the complex is reminiscent of the shared cultural elements between the member countries. And like the friendship between these Nordic nations, the stainless steel will continue to endure. (MH)



# IMOA news

## IMOA's 31st AGM

The breathtaking Rocky Mountains of Colorado provided an impressive backdrop for IMOA's 31st AGM in September 2019. Kindly hosted by Climax Molybdenum, around 140 delegates attended the two-day event.

Experts from across the globe presented papers on a range of subjects including the direction of the global economy, the outlook for molybdenum amidst current uncertainty, sustainability, supply chain transparency, leveraging molybdenum in marketing special steels and the prospects for molybdenum in China. Six industry experts also led a lively panel discussion, offering insight into longer-term growth in the molybdenum market against a backdrop of global economic slowdown, trade wars, new technology and environmental trends.

Uniquely, delegates were transported by ski gondola to experience the stunning Vail mountain views en route to both evening dinners. Entertainment



▶ IMOA members and guests enjoy the fantastic view in the mountains.

included performances from a Native American dancing troupe, a Native American flautist, and the mesmerizing musings of Nina Gabianelli from the Aspen Historical Society on Indian Tribe History before sitting down to the best of Colorado dining. As the formal conference came to a close, one of the highlights of the week was a visit to the Climax mine, a state-of-the-art facility with over 100 years of history.

▶ Smiles all around at the 31st AGM.



## In memoriam: Dr. John A. Shields, Jr. May 12, 1946 – December 14, 2019



Long-time consultant, Dr. John Shields will be greatly missed by his friends and colleagues at IMOA. He was our expert in molybdenum metal applications, production and fabrication. For over 25 years, he helped shape IMOA as an organization. John authored our brochure on molybdenum metal and also played an important role in editing and writing articles for MolyReview. Sharing his immense knowledge, he answered many questions by users and specifiers of molybdenum metal over the years.

Working with John was an absolute joy. He was always there to help and never shied away from a difficult task. He had great patience in getting things just right. John knew so much, and what he did not know, he spent countless hours researching until he understood. John was immensely dedicated to both the pursuit of knowledge and sharing that knowledge. Memories of John, his kindness and his prolific career will live on through his loved ones, friends and colleagues for years to come.

## Second Chinese Molybdenum and Steel symposium a success

Following the success of the inaugural Molybdenum and Steel symposium held at Shanghai University in November 2018, a second event was attended by an international group of metallurgy experts and metal industry leaders in Xi'an in November 2019. The theme of this year's symposium was molybdenum alloyed stainless and high alloy steels.

Hosted by the Jinduicheng Molybdenum Company, the Stainless Steel Council of China Special Steel Enterprises Association (CSSC), China Nonferrous Metals Industry Association-Molybdenum Branch and the International Molybdenum Association, the event attracted over 200 delegates. Presentations were given by worldwide industry experts and scholars from the People's Republic of China (PRC) on a wide range of subjects, including the use of molybdenum alloying in ultra-high strength steels, the trend of molybdenum alloyed heat and corrosion resistant special

steel in China, development of additives to molybdenum grade steel, the effect of molybdenum on the properties of high-alloyed products, and the current use of molybdenum in special steel.

Tim Outteridge, IMOA's Secretary General, commented "the development of excellent quality, high-performance steel products is essential to sustainable growth in China. This symposium offered the opportunity to share knowledge and best practice within the industry to enable continued progress in this area."

Contributions to the *first* 2018 Molybdenum and Steel Symposium in Shanghai have since been published in five papers in the *Advances in Manufacturing* journal and can be downloaded as a set of proceedings from the IMOA website: <http://bit.ly/2018SteelSymposium>.

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Coiling of red hot bar, a step in the production of dowel bar at the steel mill. © Outokumpu