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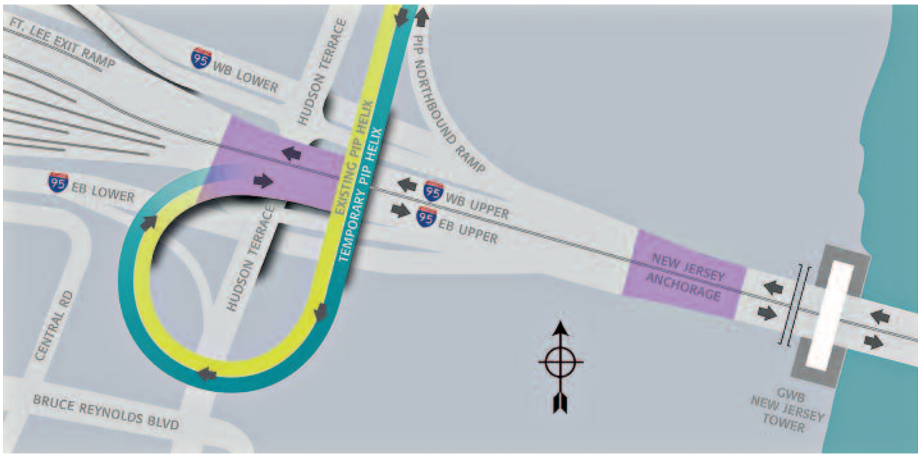
Restoring the George

Hundreds of thousands of vehicles hurry across the George Washington Bridge every day. The aging bridge is one of only three ways to enter Manhattan from New Jersey by car, and it sees more vehicle traffic than any other bridge on Earth. But it is in need of critical repairs. Coming to George's aid is Type 316LN stainless steel rebar, which will revitalize the crumbling concrete decks of this most important passageway.

First built in 1931, the George Washington Bridge spans the Hudson River, connecting the Washington Heights neighborhood of Manhattan with Fort Lee in New Jersey. An unrivaled average of 300,000 vehicles cross the bridge every day. Its importance as a travel route means that any type of disruption poses a major challenge to both commuters and those tasked with maintaining traffic flow.

Repairing giant George

When it debuted during the Great Depression, the George Washington Bridge was a state-of-the-art engineering marvel – twice as long as any other suspension bridge before it. The George is truly massive; its highest towers rise 185 meters above the Hudson, and its upper and lower decks carry eight and six lanes of traffic, respectively. Despite its size and grandeur, after nearly 88 years of heavy traffic, drastic temperature swings, and exposure to both de-icing and marine salts, this vital passageway is in grave need of repair. Indeed, minimal updates have been made to the bridge since 1961, when the lower deck was added. To meet current repair needs, the Port Authority of New York & New Jersey (PANYNJ), the owner of the bridge, is undertaking a decade-long, 1.9-billion-dollar rehabilitation initiative. 'Restoring the George' consists of 11 individual projects, each with staggered starting dates to minimize impact on traffic.



Palisades Interstate Parkway (PIP) on-ramp helix at the New Jersey end of the bridge where Type 316LN stainless steel rebar is being incorporated. A temporary on-ramp has been constructed to divert traffic during the restoration. © The Port Authority of New York and New Jersey

Currently, one of these projects is incorporating approximately 1,300 tons of Type 316LN stainless steel concrete rebar, for both pre-cast components and cast-in-place deck segments. This rebar ❯

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Cast components being lowered into a HIP vessel.
© Bodycote

will be integral to replacing the decks of the massive helix on-ramps and of the merging lanes that lead on and off the bridge into New Jersey. However, any construction has to be carefully planned to avoid the blocking of lanes, which would cause major delays to commuter traffic. To this end, work takes place only one or two lanes at a time, from midnight to 5am, mostly on weekends. The installation of durable stainless steel instead of lower-cost carbon steel rebar will help to extend the service life of the bridge decks significantly, minimizing future repair, maintenance needs, and associated traffic delays.

Stainless steel rebar to last for generations

New York City winters and salty coastal air, combined with an unparalleled level of traffic, mean the George Washington Bridge takes an exceptionally hard beating. During winter, the bridge is frequently exposed to aggressive de-icing salt slurries that permeate the bridge deck. The salts eventually reach the steel reinforcing bar embedded in the concrete. Regular carbon steel rebar corrodes in this situation. Rust forming on the steel surface is porous and more voluminous than steel. As it exerts pressure on the concrete from within, the concrete spalls and crumbles, allowing even more salts to penetrate the deck, further accelerating deterioration.

Even though the George Washington Bridge is nearly 90 years old, it adapted to increasing traffic by adding a second deck below the original one in the 1960s, and is now the busiest bridge in the world. © The Port Authority of New York and New Jersey

New York City's high level of chloride salt exposure, therefore, necessitates an especially corrosion-resistant solution – Type 316LN stainless steel rebar. Thanks to the addition of 2% molybdenum, this alloy has excellent corrosion resistance to chlorides from de-icing salt or marine atmospheres. Stainless steel rebar is a small, but growing market segment in construction where local conditions are especially hard on carbon steel rebar, such as in North America's 'Snow Belt', or along its coasts. The corrosion of carbon steel rebar is the primary factor in the deterioration of concrete, so molybdenum-containing stainless steel rebar will not only last longer than carbon steel rebar, but also contribute to the longevity of surrounding materials. The result is a bridge that will need comparatively little maintenance over its lifecycle.

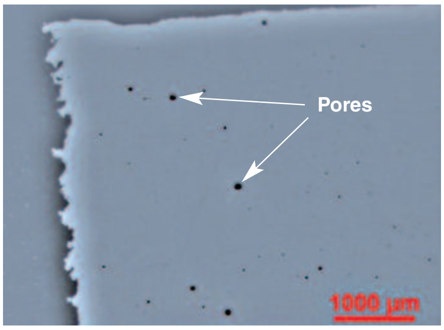
Because stainless steel rebar is not affected by chlorides that permeate the concrete over time, the traditionally used thickness of the concrete cover, needed to delay carbon steel corrosion, can be significantly reduced. The bridge deck can therefore be made lighter, reducing the load on the foundations and support structures, which in turn can be downsized as well, leading to overall cost savings. The total project cost increase, as installed, is consequently quite modest when using stainless steel rebar, typically in the range of 1 to 10%. The much longer service life of the structure translates to significantly lower life cycle cost.

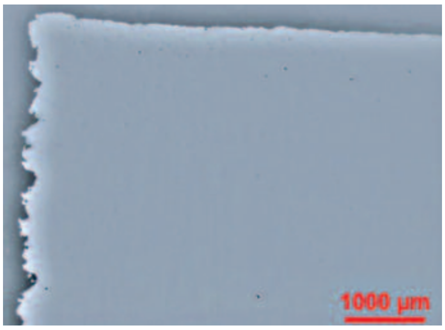
Although the harsh environment, age and traffic volume collectively pose a unique challenge in maintaining the George Washington Bridge, the use of stainless steel rebar ensures that it will be a long time before its deck has to be restored again. With the help of molybdenum-containing stainless steel, the George will provide a safe passage over the Hudson, with minimal disruption, for many generations to come. (FS, KW)

Moly is HIP

Improving the safety and efficiency of technologies and minimizing their environmental impact often depends directly on the development of better materials. Hot isostatic pressing (HIP) technology has been at the forefront of this area for decades. Recent advances improve the productivity of making HIPed parts and reduce their cost. Molybdenum metal components are crucial to HIP furnace performance.

A hot isostatic press, or HIP, is essentially a furnace built inside a pressure vessel. Originally developed in the 1950s in the quest to make man-made diamonds from graphite, HIPs are now used in a range of critical, high-performance applications. They can produce temperatures up to 2000°C and pressures twice those at the deepest part of the ocean, to process parts and materials. Holding a work piece under pressure, at 80 to 90% of its melting temperature, closes any internal pores and cracks and homogenizes the microstructure.





NNS parts often have to cope with internal voids, pores and cracks as a result of the process. These defects reduce a material's strength, ductility, and impact toughness, as well as its fatigue and creep resistance. Closing them through HIPing significantly improves material properties. The pictures show an AM part before (left) and after (right) HIPing. © Quintus Technologies

Traditional HIP applications

Most metallic parts are fabricated from standardized bar, plate or sheet products. They are then hot or cold formed, welded, machined or undergo a combination of these processes to create the final component. This approach works well for the vast majority of applications, but there are cases where it is not economical or even possible. They include materials that are not weldable or machinable, are expensive, or cannot be produced with traditional processes and components with complex geometry. For these examples, specialized production methods such as casting, Powder Metallurgy (PM) and Additive Manufacturing (AM), also called 3D printing, have been developed. These processes skip most or all of the conventional steps and produce what is called a near-net shape (NNS) part from the start.

HIP is traditionally used to reduce porosity of castings, press-sintered and metal-injection-molded PM parts, and more recently, of AM parts. It is an essential processing step in consolidating PM powders to create fully-dense NNS components. It can also be used to join different materials through diffusion bonding, such as cladding a thin layer of a high-cost, high-performance material onto a lower-cost base material.

HIP is a cost-effective technology to improve material properties such as toughness and fatigue life. HIPing thereby increases the safety and reliability of materials and components, extending their service life and reducing the danger of failure during operation. It can even 'heal' parts that have been in service and have some internal damage. For example, turbine blades that have formed pores in operation can be rejuvenated by closing those pores through HIPing, and returned to service.

Traditionally, large HIPs have been operated by a few specialized service providers around the world. They are used in many industries, including aerospace, oil and gas, automotive, tooling, electronics, power generation and medicine. Examples of parts that are HIPed include medical implants, high strength cutting tools and critical components in gas turbines.

HIP/Heat-treating combo

HIPing used to be a relatively slow process, not only because of the procedure itself, but because the vessel (and the HIPed parts in it) can take hours to cool down. Unfortunately, many materials require rapid cooling or quenching after annealing, often followed by further heat treatments to achieve the desired properties. These steps are usually outsourced, adding to lead times and cost.

Engineers at a long-established company, now known as Quintus, were able to overcome this constraint through an innovative wire-wound design in the HIP vessel which was originally introduced in the 1950s. It permitted thin-walled pressure vessels which were strong enough to contain the high operating › pressures and were extremely safe. The reduced mass of wire-wound vessels enables rapid cooling and even quenching from the operating temperature, vastly expanding their usefulness.

Modern HIP units combine the benefits of HIPing and heat-treating, including controlled cooling in one vessel, reducing cycle time and increasing productivity of making HIPed parts that also require heat treatment. For example, the high-strength, corrosion-resistant nickel-base superalloy IN718 used for jet turbine parts is hardened by the precipitation of secondary phases within the metal matrix. After HIPing, parts require solution annealing at around 1000°C, followed by rapid cooling. The material is then aged in two steps to precipitate the hard particles in a controlled fashion.

Processing this material directly in the HIP can reduce handling and shipping time for outsourced heat treatment as well as related transportation expenses, delay times awaiting furnace availability, and inventory costs needed to protect against such delays and extra steps.

These developments may be a key to the success of the rapidly growing additive manufacturing (AM) technology, where HIP has become a standard process used to heal internal defects. For example, one AM manufacturer is able to perform all heat treatment in the in-house HIP unit in hours rather than weeks, keeping the entire process within the walls of the AM center.

Why is Moly HIP?

Molybdenum's high melting point of 2623°C, its high strength at elevated temperatures, and its low cost compared to alternative choices have made it the preferred material for HIP furnaces since their inception. The heating elements, thermal shields, furnace racks and other internal furniture, are all made predominantly of molybdenum alloys.

The new HIP furnaces which feature heat treatments and rapid cooling use

The inside of a typical HIP furnace. Molybdenum is used for the heating elements encircling the 'hot zone', the structure that supports the elements, 'furniture' that supports the furnace load, and thermal shielding that surrounds the hot zone. © Quintus Technologies

thermal cycles that stress components in ways never before seen due to thermal expansion related stresses on heating elements and other internal parts. Molybdenum's low thermal expansion coefficient and high thermal conductivity combine to minimize thermal-cycling stresses, allowing the long service expected of these sophisticated furnaces.

Small and medium HIP units for metal AM are the fastest growing market for HIPs. Both Original Equipment Manufacturers (OEMs) with in-house AM centers and independent AM processors, who produce 3D printed parts for third parties, are purchasing systems. As AM technology grows and as companies shift from prototyping to production mode, they are realizing the economic and intellectual property benefits of operating their own in-house HIP. Such a setup permits optimization for their specific products' performance.

With the dramatically growing demand for HIP services and faster turnaround times, heat treating companies are also getting into the business. They are expanding their offerings by adding a HIP vessel to become a one-stop shop for all AM heat treating, simplifying their customers' logistics. Smaller vessels are more flexible, can run with faster turnaround times and tailored heat treatment cycles. However, as AM evolves to produce more parts simultaneously, it is expected that a need for larger vessels with high pressure heat treatment capability will arise in the future. Molybdenum has been there to support the growth of HIP technology and will continue to be there as the industry evolves. (JS, JAS)

A modern HIP unit. The molybdenum furnace is found in the pressure vessel at the center of the picture. The vessel is contained within the dark arched frame. © Quintus Technologies

Louvre Abu Dhabi: A rain of light

In the Louvre Abu Dhabi, stainless steel not only protects precious artwork, but becomes art itself. The museum's breathtaking roof contains molybdenum to withstand one of the world's most corrosive environments. Inside, rays of sunlight dance across surfaces, creating a spectacle unlike any other.

Where the desert meets the sea in Abu Dhabi, United Arab Emirates, a massive dome of stainless steel and aluminum 'stars' seems to levitate above water. But award-winning architect Jean Nouvel's design is no desert mirage. The stainless steel capped structure contains the new Louvre Abu Dhabi, a 'museum city' of 55 individual buildings, housing priceless artwork. Its design is a work of art itself, as brilliant as the pieces it houses. This extravagant new construction is part of the Emirate's wider iniative to diversify its economy by welcoming visitors as an international, cultural destination. The museum's many stainless steel features, therefore, help to guarantee the longevity of the complex as a world-class tourist destination.

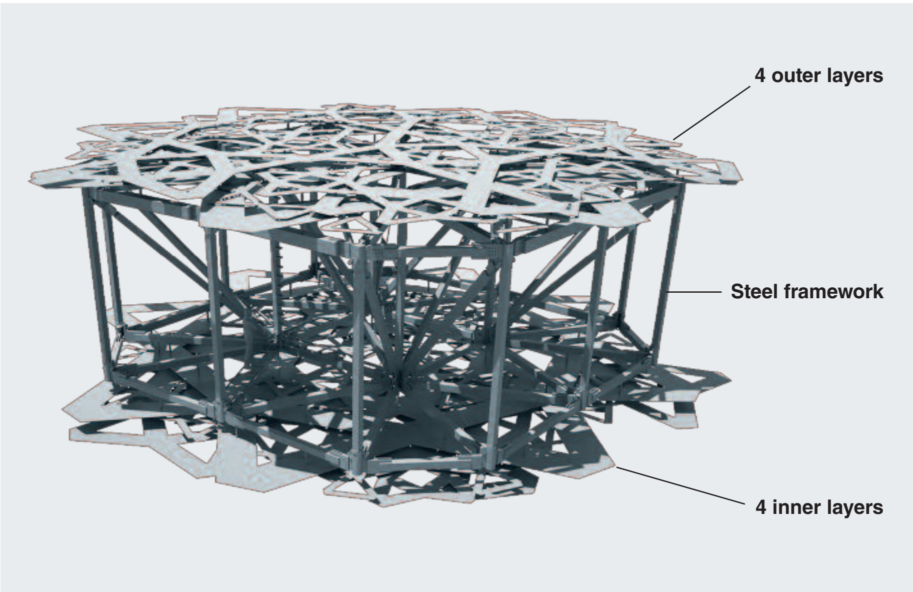
As it seldom rains in the Arabian desert, the dome did not need to be fully closed. Like an upended, woven basket, sunlight filters in through select points, creating a one-of-a-kind spectacle known as the 'rain of light'. The woven design harkens back to the interlacing of woven palm fronds traditionally used on Emirati roofs as protection from the sun. Throughout the day, scattered fragments of light float according to the course of the sun like levitating diamonds.This dramatic effect is inspired by the semi-covered streets of a special kind of Arab market, known as a souk. Cut out against the environing darkness, one can almost grasp the sun's rays as they mingle with minute particles of dust in motionless suspension.

A nebula of metal stars

Sunlight enters the dome through a 'nebula of stars' weighing over 7,500 tonnes – as much as the Eiffel Tower. The roof is composed of 7,850 star-shaped elements superimposed over eight layers. The stainless steel clad outer layers are separated from the aluminum inner layers by a five-meter high standalone steel structure. In total, the layers contain nearly 460,000 geometrically distinct intersections, linked by over 410,000 connection points. In addition to their differing shapes, the stars' angular arrangement varies from one layer to the next, which complicates the passage of light.

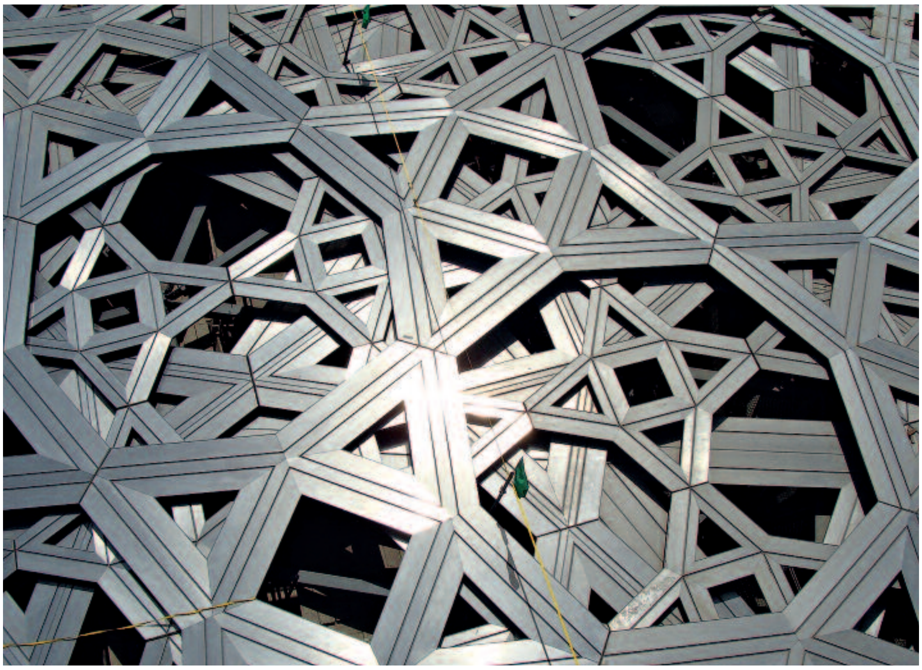
The steel structure separating the layers is made of 85 monumental elements, or *Super-Sized Elements (SSE)*. The SSE are subdivided into 11 unique modules, each weighing on average 50 tonnes. They are welded or fastened by bolted plates. These SSE were coated with paint that reflects the infrared energy of sunlight, contributing to lower temperatures inside the structure and also to enhanced color vibrancy.

With a simple shape – a square surrounded by four triangles – the stars produce intricate arrangements similar to those found in traditional Arab art and architecture. The result is both visual complexity and excellent passive insulation for all the museum's facilities. By day, the dome blocks 98.9% of the sun's light, which helps maintain a stable temperature for both the art collection and vistors. The remaining sunlight dances in a continuously moving spectacle. At night, the process reverses as 4,500 projectors cast light out of the dome in fragmented beams, transforming the museum into an imposing, seemingly moonlit crystal, visible far beyond the Abu Dhabi shoreline.



Four outer layers made of aluminum and stainless steel, and four inner layers made of aluminum, separated by a five-metre high standalone steel structure. © Jean Nouvel Architecte and © Waagner Biro Stahlbau AG

The roof filters the stark Middle Eastern sunlight and creates a mysterious atmosphere with constantly changing lighting conditions. Germination by Giuseppe Penone © Photography Roland Halbe – Louvre Abu Dhabi – Architect Jean Nouvel



The dome's intricate pattern of "stars" is clearly visible from above. © Waagner Biro Stahlbau AG

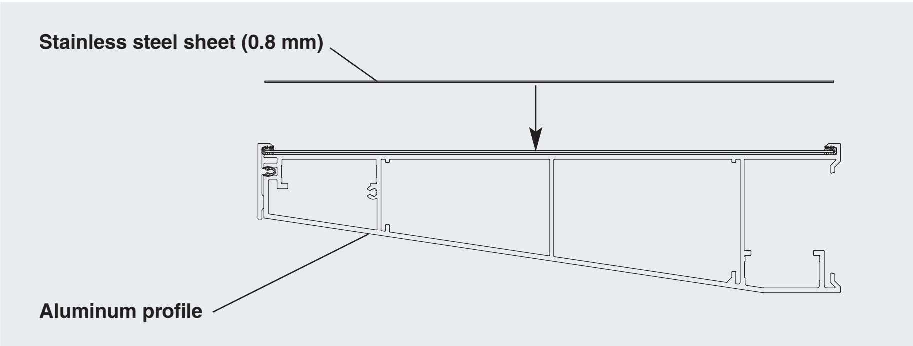
The engineers and the architect used stainless steel for the four upper layers of the dome, which are the most exposed to the climate, but also the most visible. The 4,481 stars of the upper layers were all clad on their upper face with 0.8-mm thick sheets made of duplex stainless steel. These sheets were first welded to each other, then fastened to the aluminum substructure through neoprene-insulated joints to avoid any galvanic corrosion of the aluminum by the stainless steel. To completely separate the two metals, the underside of the stainless steel sheets are clad with an anti-corrosion protective polyethylene film. The cladding takes on the exact curvature of the surface of the stars; an angle of slightly less than 180°, allowing for the low height of the dome of 36 meters and its wide diameter of 180 meters, accentuating its lightweight effect.

A study of the sun

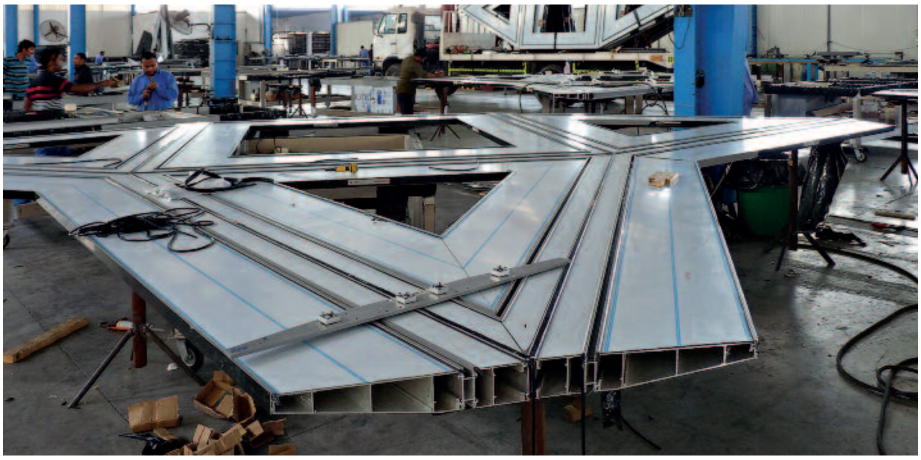
Designing the roof of the Louvre Abu Dhabi was no small feat. Engineers analyzed the course of the sun across the site over 365 consecutive days and used cutting edge information technology as well as the most recent BIM (Building Information Modelling) applications to calculate the ideal arrangement of the dome's stars. In order to test the light's path in real conditions, they built a mock-up on a scale of 1/200 of the intended size, followed by a life-sized model, representing a six-meter diameter subsection of the dome. In total, the design and construction of the dome took over five years.

Stainless steel for durability and aesthetics

In addition to its complex geometry, the dome's materials play a decisive role in the 'rain of light'. Extruded aluminum was used as the substructure of the eight layers of stars for its ease in terms of manufacturing, implementation, weight and corrosion resistance, but also for its light reflecting capabilities.



Cladding of an aluminum profile. © Waagner Biro Stahlbau AG



Cladding of one of the aluminum stars with molybdenum-containing stainless steel in an Abu Dhabi plant. 500,000 profile parts were assembled in two profile machining centers. © elumatec AG

The Louvre Abu Dhabi inhabits one of the most corrosive environments in the world; an island exposed to desert heat and high humidity, surrounded by salty ocean spray. To resist this extreme environment, 3% molybdenum-containing type 2205 duplex stainless steel was used. Thanks to its higher molybdenum content, this stainless steel is significantly more corrosion-resistant than the 2% molybdenum-containing Type 316 austenitic stainless steel that is often used in less aggressive coastal applications. The matte 2E surface finish avoids creating excessive glare that could be blinding in the sun. Additionally, the stainless steel reflects the tints of the changing colours during the course of the day, and contributes to the festival of lights produced by the Louvre. Elsewhere in the museum, grating, walkways, and meshing are also made of 2205 duplex stainless steel. In all, 300 tonnes of this material have been used in the construction.

Reinforced protection against the sea

Stainless steel rebar was used to reinforce the 4,500 leak tight concrete piles drilled to nearly 15 meters below sea level that support the entire platform of the museum. The same rebar was also used in the 280 submerged columns, the concrete cut-off walls, and in a tailor-made 'protective wall' that safeguards the museum against any threat from the sea such as storms or collisions with ships. The alloy selected for these applications was 2304 duplex stainless steel, with 0.3% molybdenum. Combined with the ultra-high-performance concrete, this alloy offers both a guarantee against corrosion and a high ductility.

Safe with stainless steel

The admirers of the Louvre Abu Dhabi's valuable collection can rest assured. The pieces will not be impacted by ocean salts or desert sun. Resting on a stainless steel reinforced throne of concrete piles, protected by a stainless steel reinforced moat, and crowned with a stainless steel dome, the artwork and its visitors are safeguarded all around by this amazing material. Light raining in through its roof, the mirage-like Louvre Abu Dhabi is a mystical, yet calculated cultural artefact, one that will stand for many generations to enjoy, thanks to the durability imbued by molybdenum. (TP)

At night, the dome sparkles from the inside. The stainless steel reinforced concrete walls in the foreground protect the museum from the sea.

Moly is a Jack of all trades

At the ends of the earth, strange machines patrol the oceans in search of oil deposits to drill for. Meanwhile, their cousins stand tall in some of the world's gustiest seas, installing or maintaining offshore wind turbines. Both of these highly specialized vessels, lifted up by jackup legs, brave extreme conditions on the sea to help meet our global energy demand. But constant exposure to high winds and enormous waves means 'jackups' must be made of strong materials. Molybdenum-containing steel allows these special machines to stand up to the forces of nature, while ensuring the safety of the people who work and live onboard them.

A jackup rig is a most unique sea creature; it is a self-elevating, mobile platform with movable legs. With its legs raised high above the water, it is reminiscent of something from a science-fiction film set. Despite the futuristic appearance, jackup rigs have actually been around since the 1950s, when the aptly named 'Rig No 1' was manufactured in the United States. Today, there are more than 500 rigs in operation around the world.

Jackup rigs used to be deployed almost exclusively for oil and gas exploration and well drilling. They are easily relocated, and as a result, are much less expensive than fixed offshore platforms, which are constructed on already explored wells. Jackup rigs are also cheaper to operate than drill ships, which are still used for deeper waters. However, in the last few years, the jackup mechanism has increasingly been utilized in the renewable energy sector for wind turbine installation, repair and maintenance vessels. These vessels offer a stable work bench for wind turbine installation by lifting a platform up over the roiling waves. Current lifting cycles are faster than once a day – a rapid increase over installation times just a decade ago. This increase in efficiency means that an 80-turbine wind park can now be constructed within three months instead of a couple of years, dramatically reducing the cost of a new wind energy project.

The Pacific Osprey jackup vessel is lifted off the sea and remains stable and disconnected from the waves below for the installation of a wind turbine. © Swire Blue Ocean

Standing on the bottom of the ocean

While a jackup vessel is on its journey, its legs are raised high above the water. When it arrives at the desired position, the legs of the rig are lowered (or 'jacked') into the water, and driven down onto the sea floor. The weight of both the barge and additional ballast water drive the legs into the seabed. When the legs are safely in place, the entire floatable platform is 'jacked up' off the surface of the water, isolating the platform from the motion of the waves and tides underneath and keeping it stable.

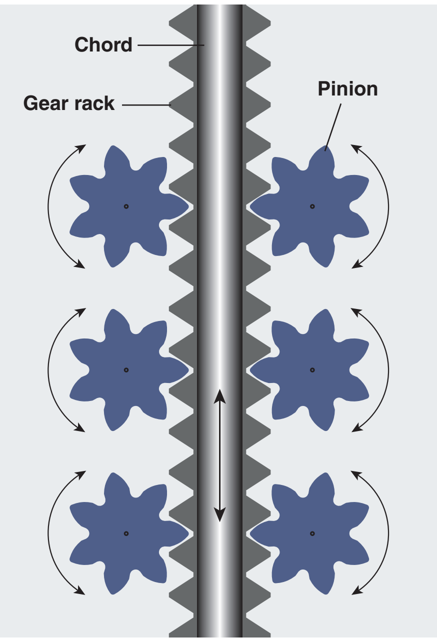
Traditionally, jackups are used in shallower waters, which are less than 120 meters deep. However, the legs of jackups vary in length depending on their target market. For oil and gas drilling they are increasingly made longer, now allowing for operation in waters as deep as 150 meters. For wind applications they tend to be shorter ❯

as the majority of turbines are installed in water depths of 40 meters or less.

Oil and gas rigs are often platforms which are towed by boat to their destination. They may remain at the same spot for months or even a year. Wind installation vessels, on the other hand, look more like a boat. Typically they need to change position daily and are therefore self-propelled.

By the skin of their teeth

Most rigs have a rack and pinion jacking system, where the pinion gears drive gear bars, called racks, which form the corners of each of the legs of the rig. The protruding 'teeth' of the rack connect with the pinion gear, which incrementally pushes the leg either up or down. At any given time, the weight of the platform combined with the stresses from this driving action impose a concentrated load on just a couple of teeth in the rack. This requires a very strong steel, typically a 690 steel with a minimum yield strength of 690 MPa, containing up to 0.6% molybdenum.



The corners of a leg are made of two heavy-walled chords welded to the gear rack. Motors drive the pinions that move the gear rack up and down, which lowers and raises the vessel.

Inspecting the high-strength steel racks and their 'teeth' on the legs of a jackup vessel. © DIRA Group

The thickness of the rack depends on the length of the leg, the load of the platform and the frequency of raising and lowering the legs. The rack is at least 100 millimeters, and for the newest wind turbine installation vessels, up to 250 millimeters thick. Only a few companies worldwide can produce and fabricate such heavy plates and sections of high-strength steel.

To reach the necessary yield strength at these thicknesses, the steel must be quenched and tempered, and alloyed with molybdenum to produce consistent properties throughout the thickness of the steel. Together with carbon and nickel, molybdenum creates an exceptionally strong and tough steel. Furthermore, the addition of molybdenum helps the steel to maintain its excellent mechanical properties even after high temperature fabrication processes such as flame-cutting and welding.

There is a great difference between rack wear in rigs that are moved every few months and offshore wind installation vessels, which are moved daily. Also, some parts of the racks see more wear than others, depending on the depth of water where they are mostly used. Because the usage and wear of these jackups is so variable, they are inspected and overhauled every five years.

Shifting paradigms on the seas

Just a few years ago when global oil prices were relatively high, and exploration to find new reserves was cost-effective, the demand for jackup rigs, especially those designed for deeper waters, was very buoyant. The weaker oil market of recent years and improved recovery efficiency of existing wells have slowed offshore exploration, and consequently, the utilization rate of jackup rigs.

Nevertheless, jackups aren't ready to give up their sea legs yet, nor their role in offshore energy activities. Now, these vessels too are shifting paradigms to make wind power more cost-effective. ›

The 'Pacific Orca' vessel moves to a new location. © Swire Blue Ocean

The shape of gear racks is produced by flame cutting heavy plates. © Dillinger

Just ten years ago, wind turbines had to be assembled from vessels that bobbled unstably in the water or from over-sized, expensive offshore cranes. Today, installation vessels with jackup legs provide a firm, self-moving platform for faster operation, improving the viability and profitbility of the offshore wind sector. In this vein, molybdenum-containing steel has played a small but indispensable role in advancing renewable power. Energy prices and trends may rise, fall, and shift like the roaring tides on which the jackups surf, but here the application of molybdenum remains as unwavering as the jackups' legs themselves. (AH)

Stainless steel seals the deal

Beneath the surface, under streets and buildings, an 'invisible' infrastructure humbly helps to make modern life more efficient, convenient and safe; pipelines that transport drinking water, gas, oil and waste water to and from buildings and across cities, countries and continents. Burying these pipes underground protects them from most forms of damage, and saves space above ground. However, ageing, corrosion, wear and ground movement pose challenges to their integrity, and can lead to leaks which are difficult to locate, access and fix. A rubber pipe seal, secured in place from inside the pipe with molybdenum-containing stainless steel expansion rings, is a convenient and durable solution.

Traditionally, repairing or replacing a buried pipe involves digging up the ground to access the affected section, often beyond the immediate area of the leak. Such repairs can lead to traffic disruption or interruption of plant and building operations, as well as environmental damage. Additionally, the damaged pipe may lay beneath other pipes or fixtures, meaning it is not directly or easily accessible from the surface. To complicate matters further, the exact location of a leak can be difficult to pinpoint and shutting down the pipe for repair may in itself cause problems, leaving businesses and customers without essential services. A repair system that fixes the pipe from the inside can solve many of these issues, because inspectors and repair personnel can use existing access points without disturbing the surface, and, if necessary, without disrupting services.

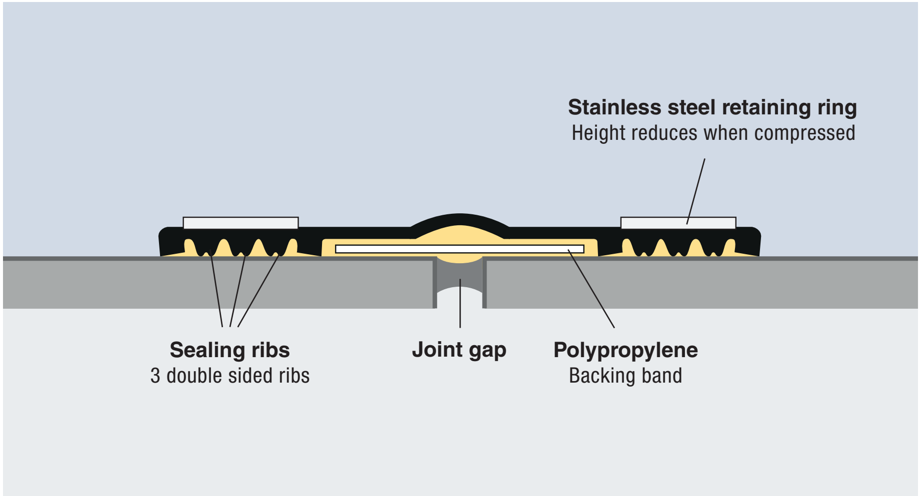
An inside job

Internal pipe repair methods including relining, are collectively called 'trenchless rehabilitation techniques'. They are generally quicker and less costly than open-trench methods, because they avoid or minimize excavation and backfilling; they are also safer and less invasive. Installing a relatively narrow rubber pipe seal, right at the affected ❯

area, is one of the most cost-effective and quick methods to repair a localized leak or offset joint. This internal sealing system can be used in any pipeline that is large enough to be accessible by people.

Rather than replacing or repairing the pipe itself, or relining lengths of pipe, the system applies a 'patch' locally. The leaking section is first evacuated, so that the repair team can enter the pipe using the nearest access hatch. After they have located the leak, they clean the inside surface of the pipe and prepare it for sealing. Usually between 30 and 50 centimeters wide, the rubber strip is similar to the tube inside a tire, and extends to fit around the entire inner circumference of the pipe. It incorporates sealing ribs at both edges of the strip. The sealing ribs, which face the inside of the pipe, are then themselves held in place with two stainless steel expansion rings, creating the seal.

These specially engineered, stainless steel rings are typically three to five millimeters thick and are manufactured with a gap. With the help of a hydraulic extender the gap is expanded, pressing the ring against the rubber seal. Once expanded, a stainless steel section is slotted into the gap, locking the ring in the expanded position and maintaining the sealing pressure.



Schematic of the sealing system. © Amex

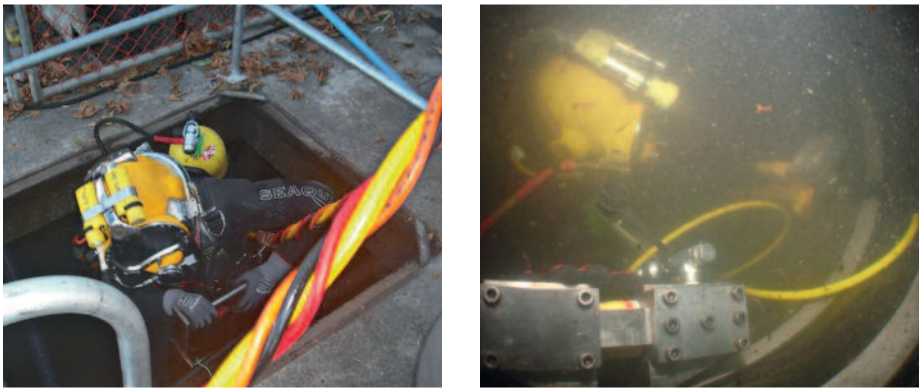
After the seal and stainless steel bands are installed, the seal can be pressure tested to ensure it is sound. Because the elastomer seal is flexible, it will remain in place even if the pipe moves. Movement can arise from external pressure, or from two different pipe diameters being sealed together.

Such internal seals come in contact with a range of substances, including potable water, gas, oil, and sewage. They are also used in industrial applications such as cooling water for power stations or process plants. To ensure the seal can stand up to such a wide range of possible liquids without degradation, the expansion ring is usually made of molybdenum-containing stainless steel, a material known for its exceptional resistance to corrosion in a variety of environments.

Stainless steel ensures durable repair

Different grades of stainless steels may be selected, depending on the corrosivity. They typically include Type 316 austenitic stainless steel with 2% molybdenum and, the more corrosion resistant, 2205 duplex stainless steel with 3% molybdenum. The latter is used in more aggressive applications, for example, in waters with higher chloride contents which are encountered in pipelines which are installed undersea ❯

Installation of the internal pipe sealing system. © AMEX or at desalination plants. Proprietary versions of the system are guaranteed to last for fifty years. The oldest examples have been in use for around forty years, but show no sign of degradation to either the seal or the sealing ring.



If necessary, the system can even be installed while the pipe is in operation. © AMEX

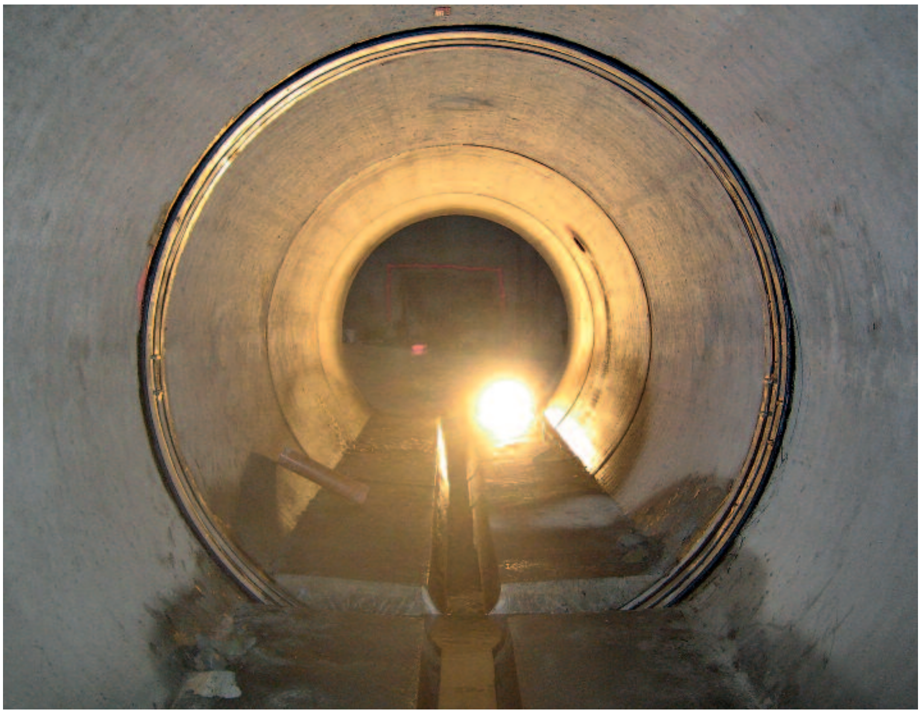
This internal sealing system was developed to stop leaks and to be more reliable than a spray coating that is not flexible and tends to both crack and degrade over time. It has been used successfully around the world, and can return pipes to normal service much more quickly than traditional methods. Additionally, these seals do not require completely dry conditions, as some other systems do, and can even be put in place by divers without emptying the pipe.

From distress to success

At the Killingholme power station in the United Kingdom two faulty joints were discovered in one of the 1.8 meter diameter condenser return pipelines. The joints, located below the generator transformer compound, were not accessible from above, and were badly misaligned. Adding to the problem, the station's cooling water is taken directly from an estuary, requiring the replacement seals to have good chloride resistance. An abrasion-resistant rubber seal with 2205 duplex stainless steel compression rings provided an ideal solution for the repair, which took only two days to install. Its low profile does not obstruct the water flow and also eliminates the need for chemical adhesives and their associated hazards. The rubber seal is able to accommodate substantial joint movement thanks to its flexibility and it has a life expectancy of 50 years or more.

The internal pipe repair system was also used during the extension of the London Underground in the 1990s. During work on the Jubilee Line, a sewer that ran just meters above the new line, was at risk of losing integrity from the vibration of the drilling machines, which threatened to bring work to a halt. Using this inner-pipe system with a Type 316L stainless steel compression ring, the sewer was successfully sealed from the inside, preventing leakage or collapse, and allowing the drilling to continue.

As these and countless other examples show, underground pipes perform crucial, but invisible roles. Accessing them externally is very expensive and creates an often disproportionate amount of damage and disruption compared to the size of the area that needs to be repaired. By accessing the leak from the inside, pipes can be returned to normal service much more quickly. Most importantly, the solution often depends on molybdenum to offer long-lasting, reliable service. (AH)



The inside of a large diameter pipe repaired with the sealing system. © AMEX

IMOA news

IMOA's 30th AGM

With its impressive modern skyscrapers and historic awe-inspiring palaces, Seoul provided the perfect venue for IMOA's 30th Annual General Meeting in September 2018, kindly hosted by SeAH M&S Corp. IMOA President Barbara Buck welcomed more than 120 delegates to the two-day meeting in the populous South Korean capital. Experts from around the world presented papers on a range of subjects including an analysis of the steel market in South Korea, the demand for molybdenum in China, and a five-year outlook of molybdenum demand globally.

Following the success of last year's panel discussion, seven industry experts led discussions on the impact of macro-economics on the molybdenum market, specifically in light of trends in oil and gas markets, potential trade wars, copper by-product mine investment, and trends in the Chinese molybdenum industry.

Delegates also experienced Korean hospitality at the SeAH dinner hosted at the Floating Island Convention Centre and at IMOA's dinner held in the impressive surroundings of Samcheonggak. As well as sampling exquisite traditional Korean cuisine, SeAH M&S Corp kindly provided dramatic cultural entertainment with a mesmerizing dance and music performance. The host closed the AGM with a fascinating tour of the Korean demilitarized zone.

Molybdenum and Steel 2018 symposium heralded a success

An international group of metallurgy experts and metal industry leaders gathered at Shanghai University in November for IMOA's 2018 Molybdenum and Steel Symposium. Hosted by both the Chinese Society for Metals and Shanghai University, and co-hosted by the China Special Steel Association, the event attracted 150 delegates to hear presentations from worldwide industry experts and scholars from the People's Republic of China (PRC) on a range of topics related to molybdenum use in high-performance steels.

The symposium was sponsored by the China Molybdenum Application Promotion Group, an IMOA initiative encouraging the development of molybdenum use by the PRC molybdenum industry. Tim Outteridge, Secretary-General, commented, "the research results and application examples shared at the symposium demonstrated molybdenum's utility in today's advanced manufacturing techniques and high-end applications."

The famous Samulnori percussion quartet delighted delegates at a dinner hosted by SeAH at the 2018 IMOA AGM in Seoul.

Suite of educational videos launched

IMOA has released a series of educational videos designed to raise awareness of molybdenum and some of its unique properties. Comprising nine videos, the series features IMOA consultants Catherine Houska, Hardy Mohrbacher and Philip Mitchell addressing questions on various aspects of molybdenum's use in the world today, including its essentiality for life and its essential role in everyday applications. The videos are available on IMOA's YouTube channel: https://bit.ly/2BrCYLh