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Behind the green curtain

For most of human history, construction methods developed in response to the local climatic conditions. But in recent decades, the seemingly infinite availability of energy, labor and building materials led architects, developers and clients to overlook these time-tested techniques. A new plant in Vietnam revisits the region's traditional building methods and combines them with modern materials to create a spectacular and sustainable green wall made of molybdenum-containing stainless steel ropes and nets.

© Oki Hiroyuki

Green façades absorb CO_2, bind dust and air pollutants, dampen noise and reduce energy requirements through shading and water evaporation. With the increasing awareness of sustainable construction methods, exciting examples of such façades are taking root, especially in large cities and other residential areas. But what about industrial areas, where large, fully air-conditioned factory production halls not only consume a lot of energy, but also pave over vast amounts of land, preventing rainwater drainage?

The region north of Ho Chi Minh City (formerly Saigon), Vietnam's financial center and largest metropolis, is one such industrial area. Since Vietnam's economic reform in 1986, the country has experienced rapid growth, especially in manufacturing. Central planning was abandoned, and foreign companies were allowed to invest and open branches. With enormous speed and little regulation, industrial parks sprang up on the outskirts of cities and continue to sprawl outward, leading to significant environmental problems.

Historically, structures in hot and tropical climates relied on open façades or wall apertures to regulate their internal temperatures. But the new factories are entirely enclosed and air conditioned at massive cost and energy expenditure. These buildings and associated roads and parking spaces also effectively seal the soil and prevent rainwater drainage, so flooding has worsened significantly in the region. In 2008, the Swiss rope manufacturer, Jakob Rope Systems, began producing its flexible wire rope nets in one such factory. With the construction of its second production facility, the company decided to change course and respond to the environmental fallout from industrial development with a breathtaking design unlike anything else in the area.

Learning from the past

What does sustainable architecture mean? There are many definitions to sustainability and theories about how to incorporate sustainable practices into the built environment. One widely accepted theory imagines sustainability as having three parts or "pillars": ecological, economic and social. The new rope net factory embraces sustainability along all three pillars, reducing both its impact on the environment and operating costs, while also improving working conditions for its employees.

The 30,000 m^2 site sits in the center of an industrial park 50 kilometers north of Ho Chi Minh City. The pioneering factory, created by rollimarchini architects and G8A, is like a lonely plant sprouting from a crack in the kilometers of near-continuous concrete. The primary challenge was to create a design that responds to a climate with both an average temperature of about 27°C and high humidity. Southern Vietnam is also exposed to seasonal typhoons and strong winds and rainfall. The architects met these challenges with a combination of both modern industrial and local traditional building techniques. Traditional Vietnamese dwellings utilized wide cantilever roofs with permeable wall constructions and planted vegetation for shade, protection from the weather and sufficient ventilation.

Following these traditional methods, the factory's overhanging roof and floor slabs shield the interior, allowing portions of the building to be open to fresh air. However, due to the height of the façade, this overhang was not sufficient to ensure complete sun and rain protection. This task is supplemented by a "hanging garden" of planters suspended from stainless steel cables. The garden-like green wall not only shades the interiors and filters pollutants out of the air, but also contributes to lowering the temperature through evaporation.

Aerial view of the Jakob factory in a sea of sealed buildings.

Sliding polycarbonate dividers, fixed in front of the factory's concrete support columns, can be closed in extreme weather.

Opening the façade for ventilation significantly reduces energy costs and emissions. Where the building is not open to the outside, mobile sliding walls made of translucent polycarbonate allow sunlight to permeate. Using natural light for interior spaces further reduces the factory's electricity needs.

In addition to conserving electricity, the factory's design also conserves space. Instead of the usual horizontally distributed, single-story factory floor plan, the architects set the required workspaces on top of each other. The site includes a three-story production building, an administration building and a covered storage and parking area, all arranged around a generous courtyard at the center of the site. Grass covered and tree-studded "planting islands" accent this courtyard. The walkways between the islands are gravel covered, allowing any excess water to seep away. This novel arrangement offers employees a park-like lounge area complete with shady trees, sports equipment, volleyball and table tennis courts.

Stainless steel nets and ropes

The vegetation of the green façades grows in planters that stretch the length of the buildings. Over six kilometers of diagonally installed stainless steel ropes carry up to nine levels of planters. The inner and outer layers of the 16 millimeter thick rope supports introduce the loads at the top into the steel roof racks and at the bottom into the base plate. The planters themselves are constructed of a base frame made of rectangular profiles and a watertight layer that is held up by rope nets stretched across the frames. All structural components are made of Type 316L stainless steel. The engineers designed the system to be strong enough to resist high wind loads and also took into consideration the increasing weight of the plants over time as they grow. In addition to the structural elements, the façade system contains a fully automatic irrigation and fertilization system. The 2% molybdenum in Type 316 stainless steel is crucial to resist both corrosion from the fertilizers and other compounds in the soil, as well as chlorides present in the environment. This is especially true for the ropes, as the tight crevices between individual wires are particularly susceptible to crevice corrosion.

The factory's green façade not only defines its character but also becomes a showcase for the rope net manufacturer. It signals to other companies to "open up" and use natural ventilation and drainage for better working conditions with a lower ecological impact. The natural lighting and temperature control achieved with the help of this stainless steel rope system is exemplary of the three pillars of sustainability working together. This project's worker-centered design will hopefully influence additional development both in Vietnam and worldwide. In the tropical, humid and coastal regions that could benefit from such designs, molybdenum-alloyed stainless steel with its improved corrosion resistance will be critical. (MH)

Frames of reinforced concrete break through the green façade and mark the entries into the building – here from the courtyard into the canteen.

Moly's in the kitchen

Is molybdenum key to the perfect sear on scallops? Type 316 stainless steel cookware provides unparalleled functionality for professional and amateur chefs alike. Pots, pans and other cooking products made with this alloy are both corrosion and high-temperature resistant. Molybdenum helps cookware to perform at the highest level for decades, even in industrial kitchens.

What makes a great meal? Usually, quality ingredients come to mind. But the materials used to prepare and cook food are also important. Just like certain oils perform better than others at high temperatures, so do certain materials. Stainless steel works brilliantly and remains unaffected even when repeatedly heated up. The ability to tolerate heat opens a smorgasbord of culinary possibilities: stainless steel cookware can sear, fry, flambé, or go in an oven at 250°C for the ultimate cooking versatility.

Metallurgy meets food science

Getting a delicious sear on a piece of meat or tofu is a delight – but it does not come easily. Robust cast iron pans can create that tasty crust and are known for maintaining a uniform heat. But cast iron is porous. To make it non-stick and give foods that perfect sear, cast iron must be seasoned by oils binding with the porous surface in a process called polymerization. The bind, which will not be removed by appropriate cleaning, will degrade in the oven at high heat. Seasoning is part of cast iron's appeal, but it significantly limits which foods can be cooked with the pan and at what temperature. Cast iron is also too heavy for some people to use, and it is prone to rust. Enameled cast iron cookware won't rust, but its coating is somewhat fragile and can easily chip.

› **Food turns from pink to brown and crispy through a chemical phenomenon known as the "Maillard Reaction."**

© Heritage Steel

Non-stick cookware is coated with polymers that prevent the sticking of delicate foods like eggs or fish but also inhibit the forming of that delicious crust. The fragility of the coating also limits the pan's life. Some non-stick coatings were linked in the past to health concerns when overheated. The harmful constituents have been phased out by major manufactures, and today these coatings are considered safe in normal use.

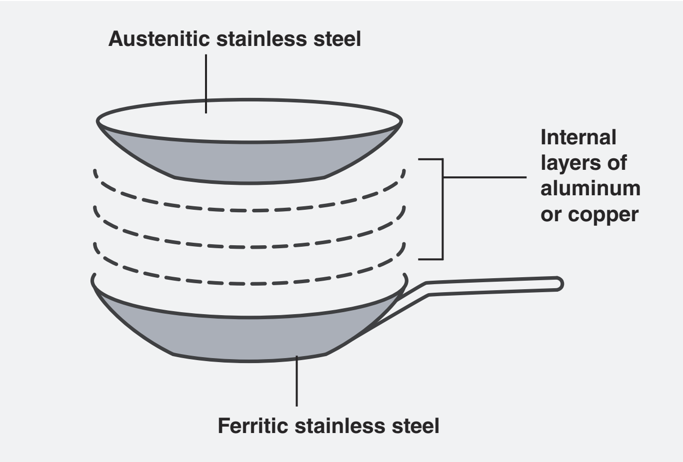
Aluminum and copper are popular cookware materials because they are excellent conductors of heat. However, these materials are reactive, and cooking highly acidic or alkaline foods can impair the quality of a dish. Most notoriously, these metals can produce a tinny taste when cooking acidic products like tomatoes.

Stainless steel needs no coating nor seasoning to brown food impeccably. Many chefs also desire the flavorful layer of "fond", the bits of caramelized food that stick to the bottom of stainless steel pans. When deglazed, this fond makes an excellent base for sauces and soups. Some cookware made with Type 316 stainless steel needs less fat or broth than other cooking materials, which preserves the original flavor of food and maintains its nutrients. And an Italian manufacturer developed a technology known as URA (Ultra Resistant Application) to make stainless steel pans more non-stick without any coating.

Austenitic stainless steels like Type 316 offer many benefits, but they are not the best conductor of heat. If cookware were made with only this material, heat would concentrate directly above the burner rather than spreading evenly across the pan's base. This can lead to hot spots over the flame, where food can easily burn without constant attention and stirring. Therefore, high-quality pots and pans also contain internal layers of aluminum or copper to boost heat conductivity. Either the entire cookware consists of multiple layers of metal, or its bottom is made of a "sandwich" disc consisting of a high-conductivity metal encapsulated by stainless steel. Some manufactures use ferritic stainless steel as the outside or bottom layer of their cookware. Why? Because ferritic grades are magnetic, and increasingly popular induction stoves only work with magnetic materials – non-magnetic austenitic cookware will simply not heat on these stoves. These multi-layered designs work on any stove and combine excellent heat distribution with all the benefits of stainless steel.

Bacteria beware

Stainless steel cookware is non-porous, preventing tiny deposits of odor and harmful bacteria from growing. This non-porous surface is also easy to clean, either by hand or in the dishwasher. Regular dish soap and baking soda or vinegar are generally all that is needed to remove any stains. One way to brighten up a well-loved pot or pan is to pour in some baking soda and water, bring it to a boil,



Stainless steel pots and pans work best when the stainless steel layers sandwich high-thermal conductivity metals such as aluminum or copper.

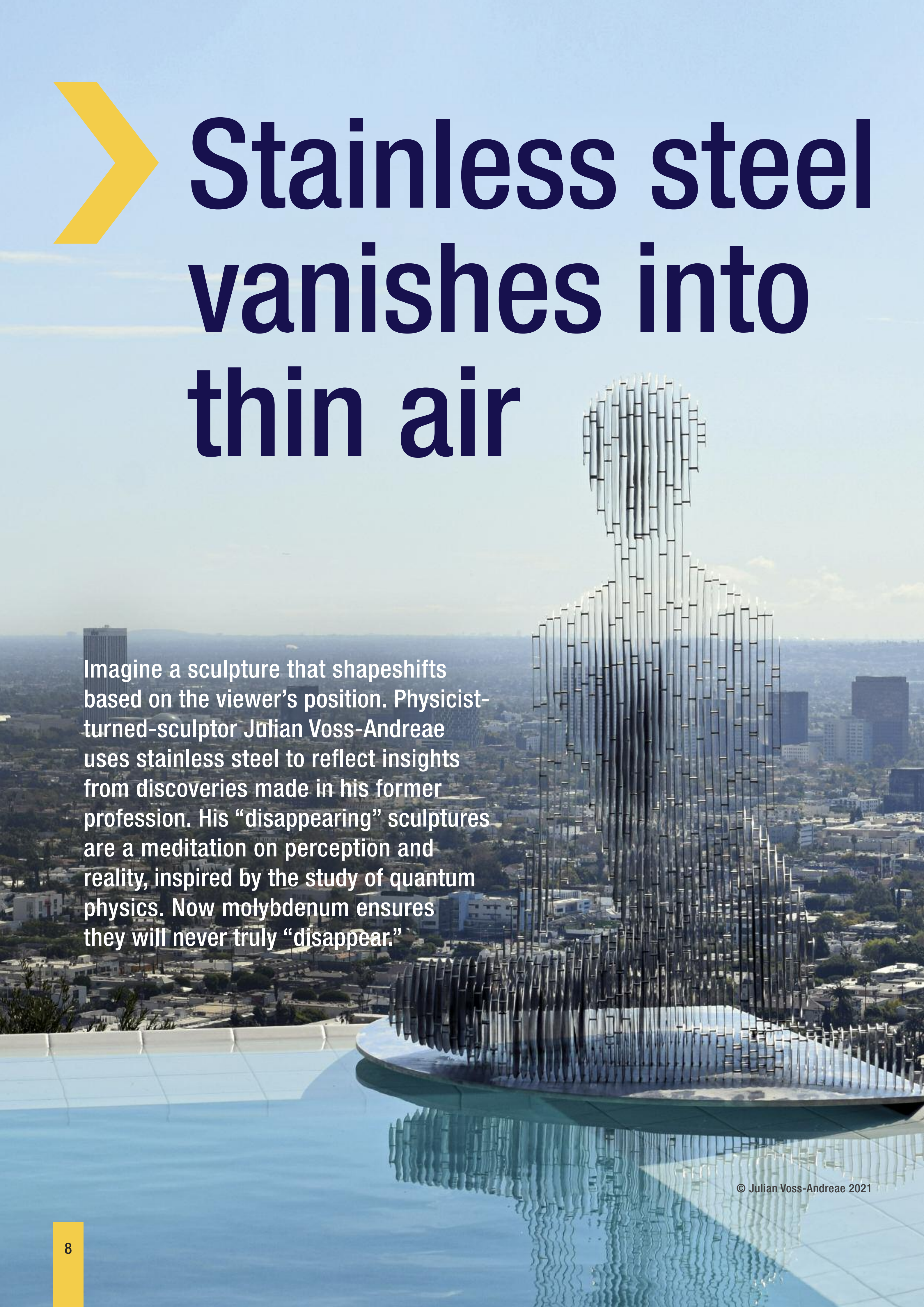
Like many stainless steel products, cookware receives scrupulous grinding, polishing and finishing.

then scrub in the film left behind by the evaporated water with a soft brush. However, in a commercial environment, stainless steel cookware withstands repeated cleaning and even disinfecting with strong detergents required by the food and hospitality industries. Because these industrial cleaning processes can corrode and damage the surface of other materials, Type 316 stainless can provide benefits to these industries. Stainless steel's smooth, non-reactive surface and cleanability make it a popular material throughout the food supply chain, in commercial kitchens, in food and beverage processing plants and in the home.

Different materials excel at different things, but overall, stainless steel offers the widest versatility paired with the lowest maintenance requirements – and it is almost indestructible. Thanks to the addition of 2% molybdenum, cookware made with Type 316 or Type 316Ti stainless steel is among the most corrosion resistant available. Cookware of this alloy not only reduces costs for industrial equipment replacement but also provides home chefs with a lifetime of culinary escapades and a family heirloom for generations. (KW)

Stainless steel cookware is durable and non-reactive.

Stainless steel vanishes into thin air



Imagine a sculpture that shapeshifts based on the viewer's position. Physicist-turned-sculptor Julian Voss-Andreae uses stainless steel to reflect insights from discoveries made in his former profession. His "disappearing" sculptures are a meditation on perception and reality, inspired by the study of quantum physics. Now molybdenum ensures they will never truly "disappear."

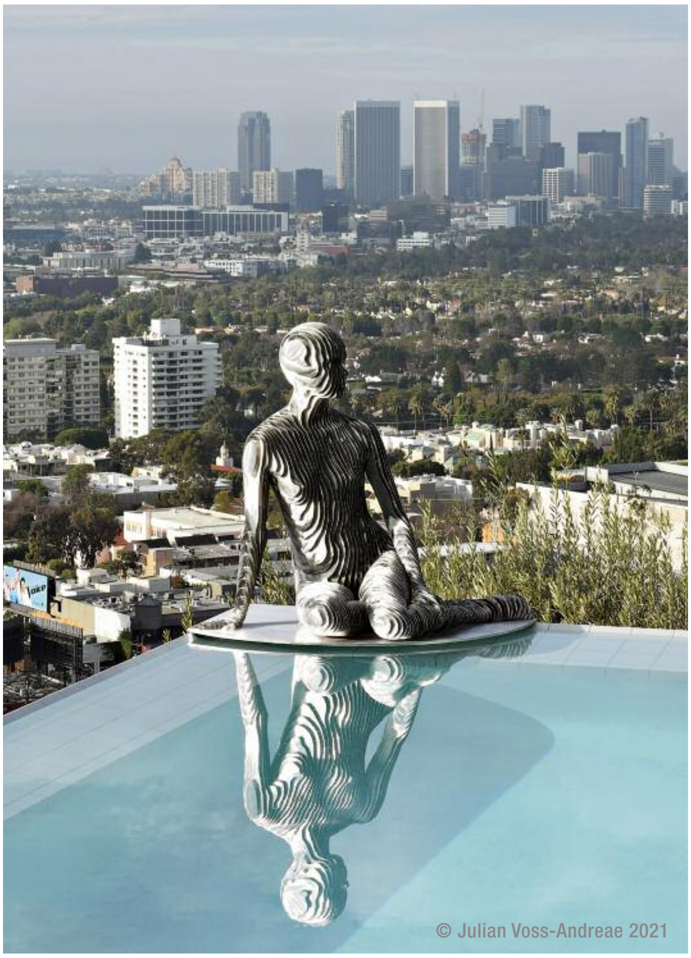
Across a field stands a sculpture of a man. His position is fixed, yet he's moving somehow. When approached, he ripples and glitches in and out of view like a hologram. Then, from head on, he disappears completely. Parallel slices of stainless steel form this trickster, the *Quantum Man*. By changing appearance based on the viewer's position, the *Quantum Man*, along with the rest of the disappearing sculpture series, nod at the limits of perception. The sculptures rely on an illusion achieved through welding evenly-spaced, thin stainless steel sheets together. However, the environment in these narrow spaces between the sheets is likely to be corrosive, if exposed to salts, especially in humid environments. This is because rain does not easily reach these spaces to clean off deposits of corrosive substances. Fortunately, the molybdenum in Type 316 stainless steel increases the longevity of the sculptures' visual impact in a range of more challenging environments.

The disappearing act

There is more than meets the eye with these mysterious sculptures. They suggest the possibility of a different world – one where everything is interconnected. The disappearing sculpture concept comes from the artist's former career as a physicist, which included work on seminal experiments at the University of Vienna.

A famous example of quantum physics is the double-slit experiment. By firing electrons from a very tiny gun through a slit onto a wall, scientists discovered bewildering properties of particles smaller than atoms. The experiment helped establish that subatomic particles don't exist in one place, as traditional physics would suggest. Instead, these particles, the foundation of all matter, exist as a wave of potentials. Most miraculously, scientists discovered that particles changed their behavior while they were being observed. When photographed, the particles fanned out as a wave. When looked at by humans, they instead formed a straight line. Scientists have repeated this experiment with increasingly large particles. Voss-Andreae worked on a double slit experiment with the largest matter at the time, a carbon "buckyball." The disappearing sculptures, which shapeshift in relation to the observer, visualize this experiment at a human scale. Rippling like subatomic waves when passed, they nod at an underlying reality quite unlike the "outerlying" one.

Stainless steel is key to the rippling effect. The metal's shimmering surface reflects colors and forms from the surrounding environment, which helps the sculpture blend in. This reflectivity requires a smooth, polished finish on the stainless steel. A smooth surface finish also helps prevent corrosion, so most of the disappearing sculpture series are made with Type 304 stainless steel. However, especially corrosive conditions necessitate the addition of molybdenum, of which Type 316 stainless steel contains 2%.



Annabelle's dramatic, but corrosive, location at the edge of a pool, high above Los Angeles, requires a durable material such as Type 316 stainless steel.

Moly, *Annabelle* and friends

Several of the disappearing sculptures benefit from Type 316 stainless steel. All are in locations that pose unique environmental challenges for metal constructions. For example, *Receptor*, *Dream* and *Annabelle* reside in southern California. *Annabelle* is a reclining figure, *Dream* is a standing figure leaning slightly forward, and *Receptor* is a seated figure. As a resident of Los Angeles, *Annabelle* braves coastal salts paired with infrequent rain washing. She also floats above a swimming pool, one of the most notoriously corrosive fixtures of the modern landscape. Swimming pools, like fountains, are usually chlorinated to keep algal growth at bay. Splashes and aerosols of chlorinated water are particularly corrosive to most metals. Newer designs of pools use salt water, which is similarly aggressive. Though *Dream* is farther inland, he leans over a fountain. He also gets little rain exposure to wash off any corrosive substances.



Like all sculptures of this series, *Dream* likes to hide in plain sight. © Julian Voss-Andreae 2021

Receptor, located just a kilometer from the San Diego coast, contains an astonishing 3000 welds. Each of these presents an opportunity for crevice corrosion. Like with *Annabelle* and *Dream*, there's little rain to wash deposits of sea salt and other chlorides from these junctures. Moreover, Type 316 stainless steel is indispensable to the design of all three sculptures. With this material, *Receptor*, *Dream* and *Annabelle* will require less maintenance overtime, remaining pristine in the California sun.

A human becomes art

All three sculptures are based on scans of real peoples' bodies. The artist uses a method called photogrammetry to precisely map each subject. The process begins by taking hundreds of 3D scans of the person from 360 degrees. He built his own rig of 170 computers with 8-megapixel cameras to capture each subject in the round. Then begins a long process using complex algorithms to "sculpt" a digital replica of the subject on the computer. He will often test and compare 3D prints of computer-sculpted parts with those he's hand sculpted in clay to get the shapes exactly right.

Receptor is one of the largest sculptures in the series. He longs for the gilded orb hanging from a nearby tree.

Once the sculpture is mapped entirely in the computer, corresponding metal sheets are laser cut and prepped for fabrication. Hundreds of hours of expert craftwork go into the welding, grinding, polishing and sanding of each sculpture.

The parts of the sculpture are numbered and assembled one by one. Building out from the center, each metal slice is placed onto the last, attached by TIG welding onto a series of dowels. Every piece is 120 grit sanded with either a medium or fine conditioning disk. Then, they are hand polished with red scotch brite pads on pins. If the sculptures are in difficult environments such as those mentioned above, they'll also receive electropolishing, a type of passivation, at the end. The thousands of delicate pieces must be crafted to perfection, involving the work of several apprentice artists.

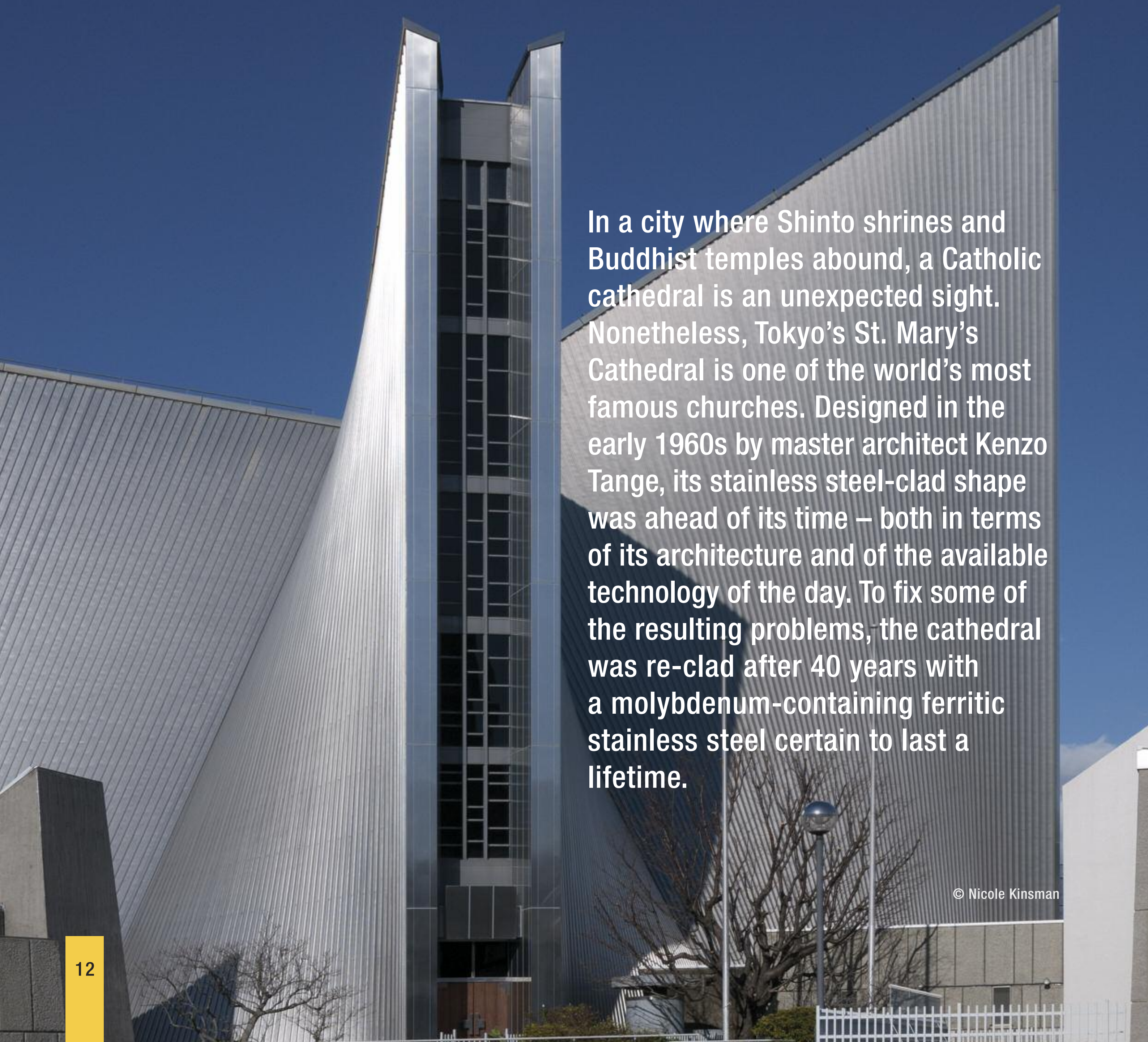
Without the benefits of molybdenum alloying, all this meticulous work could stain badly in many environments. But the sculptures will remain beautifully reflective and structurally sound under conditions that often damage outdoor art. Shimmering in and out of view, their metal skin reflects an intertwined and everchanging world. With Type 316 stainless steel in the arsenal, the vanishing sculptures' mission is only likely to expand, entangling its viewers in shared wonder. (KW)

Each panel is plug welded onto the dowels of the last, then it is resanded and polished.

The disappearing sculpture series vary widely in size, scale and figure positions.

Resurrecting St. Mary's Cathedral

In a city where Shinto shrines and Buddhist temples abound, a Catholic cathedral is an unexpected sight. Nonetheless, Tokyo's St. Mary's Cathedral is one of the world's most famous churches. Designed in the early 1960s by master architect Kenzo Tange, its stainless steel-clad shape was ahead of its time – both in terms of its architecture and of the available technology of the day. To fix some of the resulting problems, the cathedral was re-clad after 40 years with a molybdenum-containing ferritic stainless steel certain to last a lifetime.



© Nicole Kinsman

In the Catholic religion, a church is the literal House of God. Charged with designing a home for the divine, one of the 20th century's greatest architects, Kenzo Tange, dreamed up a building unlike any before. However, his pioneering design, which included a skylight roof in the shape of a cross, was far ahead of the construction methods of the 1960s. Over time, the sealant and galvanic separation failed, and rain infiltrated the church's Type 302 stainless steel standing seam roof, which also formed the walls of the building. This caused galvanic corrosion of the iron support structure beneath. By the early 2000s, the corrosion-stained stainless steel panels sometimes ripped off in typhoon-force winds because the clips holding them to the building had rusted. To ensure safety, the church needed prompt restoration. Architects, engineers and religious leaders joined to save the timeless structure. In 2007, it was re-clad with type 445J1 ferritic stainless steel, incorporating the modern building methods needed to recapture Tange's design with a more corrosion resistant alloy capable of withstanding the service environment.

St. Mary's Cathedral has the shape of a cross viewed from above. The bell tower at the bottom sits apart from the main building.

A church is resurrected

St. Mary's history begins officially in the 19th century. The original church at the site of the cathedral was a gothic style wooden structure built in 1899, which became the Tokyo Cathedral in 1920. That church held services for nearly 50 years before it burned down in 1945 during an air raid. It was not until 1960 that the planning for the new cathedral started, after Tange won a design competition. Construction began in 1963, and after 18 months, the iconic church reopened to parishioners.

By the start of the project, Tange was already a defining force in the reformation of post-war Japan. Now that World War II is largely beyond living memory, it is easy to understate the significance of his work and its influence not only on Japan but also on the rest of the world. The Pritzker Prize winning architect arguably pushed civilization towards peace and progress at a critical juncture. At just 33, he created proposals for rebuilding the recently decimated city of Hiroshima. A few years later, his design for the Hiroshima Peace Center and Park won first prize. The museum's axis spans the park, intersecting both Peace Boulevard and the site of the atomic bomb. In this way, the museum becomes a literal touchpoint between the visible horrors of war and harmonious reconstruction. The Peace Center externally signaled a commitment to lasting peace. Internally, it signaled the beginning of the search for modern Japan. Tange continued that search throughout his career with designs that incorporated both traditional Japanese architecture and modernist styles. St. Mary's Cathedral remains as one of his most celebrated creations.

A seminal structure

St. Mary's Cathedral is an enormous yet graceful structure in Tokyo's Sekiguchi district. It spreads out in all directions, embodying the lightness of a bird in flight. The outer

Galvanic corrosion

Galvanic or dissimilar metals corrosion occurs when two different metals are in direct contact and an electrolyte medium, usually water, is present on a regular basis. This situation is called a galvanic couple. When two metals form this couple, corrosion of the "anode" (less noble metal) is accelerated, while corrosion of the "cathode" (more noble metal) slows or even stops. Galvanic corrosion was first identified by Italian scientist Luigi Galvani in the late 18th century. Stainless steels are among the most noble of the commonly used building materials, so separating them from less noble metals like iron with an inert barrier is important where moisture is or could be present. To learn more about galvanic corrosion visit https://bit.ly/galvcorr on our website.

The raw, unfinished texture of the church interior invokes *wabi-sabi*, a Japanese concept honoring the beauty of transient and incomplete things.

airiness of the church betrays its dense concrete and steel constitution. The church's eight faces serve as both wall and roof, curving like hyperbolic parabolas to form a cross from above. The cross-shaped skylight roof allows natural light to enter the dark concrete interior of the church, symbolizing the light of Jesus Christ.

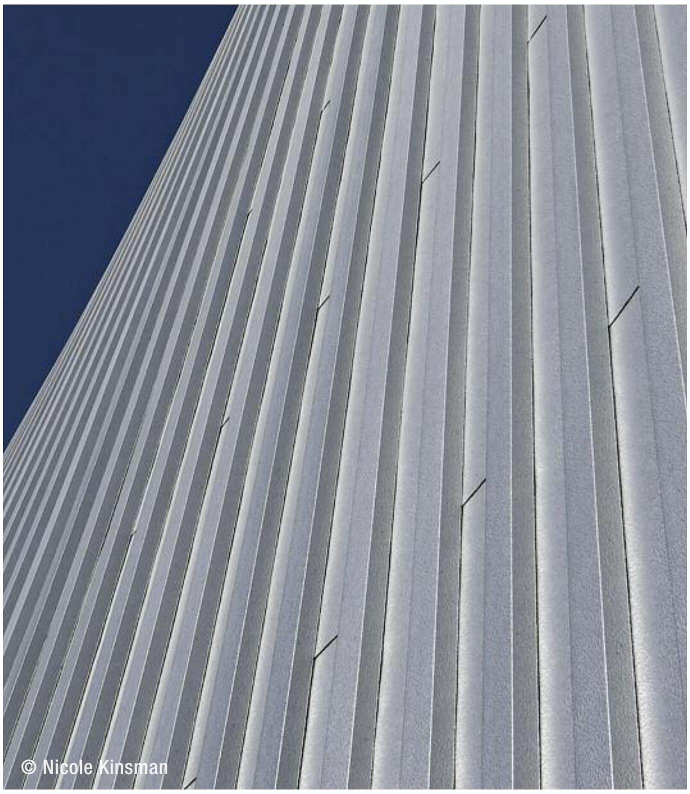
Similarly, Tange chose a stainless steel cladding for the exterior of the church specifically for its ability to reflect light and constantly change its appearance. The light bouncing off the stainless steel façade also symbolizes the light of Christ reflecting across the world. Together, the luminous stainless steel juxtaposed with the dark-toned interior concrete embody the relationship between the earthly and the divine, and how Christians believe Jesus to have bridged that divide.

However, the cathedral showed signs of water damage just a few years into its lifespan. The original skylight, made of steel and glass, was particularly susceptible to leakage and had to be covered with a second roof to prevent rain from entering the church. But this second roof also blocked the church's signature natural lighting. Fortunately, with the help of molybdenum-containing stainless steel and modern building methods, Tange's original design has been restored to withstand wind, rain and even typhoons.

The restoration

To maintain the safety and integrity of St. Mary's, both its exterior wall cladding and supporting iron structure were replaced. Ensconced in labyrinths of scaffolding, workers carefully stripped the cathedral down to its concrete skeleton, which was then cleaned and rainproofed. A special joining method allows for air to flow between the new stainless steel cladding and the inner concrete layer. This air flow dries out any moisture. The restoration and advances in glazing technology also made it possible to reopen the skylight, now constructed from glass and aluminum.

Ferritic stainless steel was chosen for the cladding, because of its lower coefficient of thermal expansion compared to austenitic stainless steel. That means ferritics don't expand and contract as much with temperature changes, making them particularly well suited for many roofing applications. Depending on the design, such thermal movement of the metal can cause high stresses in the connections and can lead to unsightly warping.



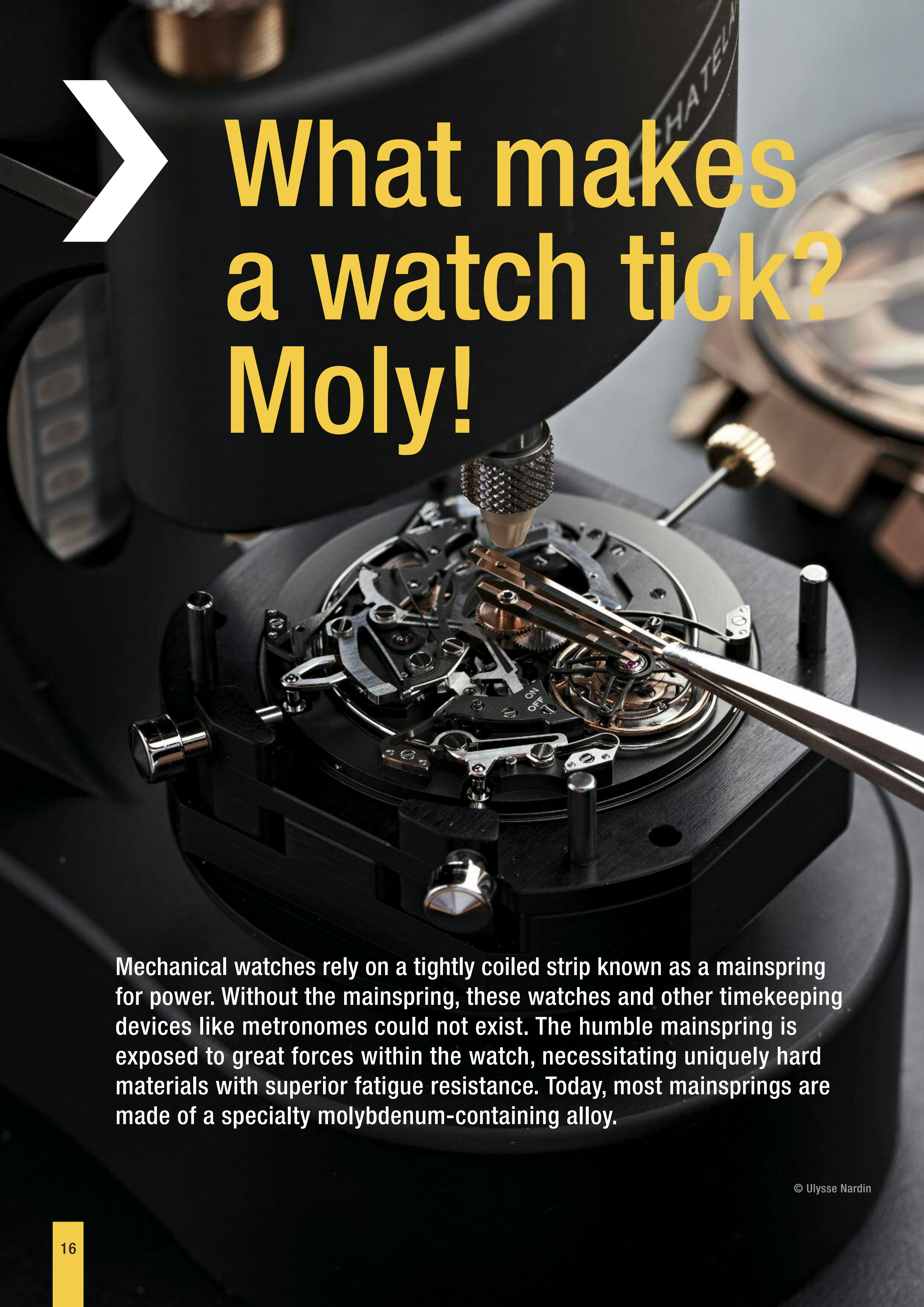
The new façade uses a classic Japanese large batten roof design, developed specifically for ferritic stainless steels. The vertical battens follow the curvature of the structure and emphasize the skyward reaching of the building.

The roof skylights extend to vertical glass walls on all four endpoints of the cross. Behind the central glass column above the main entrance sits a magnificent custom organ, the only one of its kind found in Japan outside a concert hall.

The Type 445J1 alloy used here contains around 1% molybdenum. Adding molybdenum to ferritic stainless steels improves their resistance to localized corrosion in challenging environments. Tokyo is coastal and often humid, so molybdenum is key to preserving the cladding's look and service life. Furthermore, the stainless steel cladding features a smooth, rolled-on patterned finish, also contributing to its corrosion resistance. This finish creates a more consistent appearance by diffusing light more effectively than the original flat finish. This provides a certain uniformity to the surface, hiding any oil canning or uneven spots. Importantly, modern stainless steel roof finishes like the one on St. Mary's reduce reflectivity, sparing drivers, pilots and pedestrians from glare.

Today, the symbolic light of the divine once again floods St. Mary's interior. The return of this light serves as a reminder that neither war, fierce storms, nor the ravages of time can destroy a structure entirely. So long as the spirit of the building lives in the hearts of its community, there's always a way to rebuild. (KW)

Molybdenum helps improve the corrosion resistance of the deeply-textured surface finish used on most of the church.



What makes a watch tick? Moly!

Mechanical watches rely on a tightly coiled strip known as a mainspring for power. Without the mainspring, these watches and other timekeeping devices like metronomes could not exist. The humble mainspring is exposed to great forces within the watch, necessitating uniquely hard materials with superior fatigue resistance. Today, most mainsprings are made of a specialty molybdenum-containing alloy.

Mechanical watches tell time without batteries, circuitry or an external power source. Instead, winding a watch loads its mainspring with power that sets the gear train in motion. The mainspring is the backbone of the watch. It stores energy that is released in precisely timed intervals by what's known as an escapement. The escapement mechanism prevents the mainspring from unloading all its power at once and spinning the hands of the watch like a jet turbine. Instead, the regulated energy off the escapement wheel moves the gears of the watch in increments that accurately measure the passage of time. Automatic mechanical watches work similarly, except the winding is replaced by a weight that passively generates power as the wearer moves their arm. In many watches, each part is a painstakingly crafted work of art, which approaches perfection in its mechanical accuracy. Even the seemingly simple mainspring is a metallurgical marvel, centuries in the making. Molybdenum-containing alloys play an indispensable role in the mechanical properties of nearly all watch mainsprings and certain other watch parts.

The balance spring (left) is connected by a train of several gears to the mainspring (right), regulating the release of mainspring energy to constant, second-long intervals.

The history of timekeeping

Various tools have recorded time throughout history. Sundials, water clocks and candle clocks ranging from simple to unimaginably complex kept humanity on track for millennia. Contemporary mechanical clocks and watches first appeared in Europe approximately 600 years ago. The invention of the mainspring was indispensable to modern clock and watchmaking. Before the mainspring, clocks were powered by weights. A weighted rope coiled around a pulley used gravity to power the clock. Even this design did not occur until the 12th century AD, possibly later. The mainspring enabled smaller, portable designs for the first time in history. Who invented the mainspring, however, remains a mystery. The oldest spring powered clock known dates to 1430. It is a lavish gold piece made for Phillip the Good, the Duke of Burgundy, and is housed in Germany today. Though the origin of the modern mechanical watch remains unknown, by the 16th century, portable "clock watches", sort of like an early pocket watch, were popular in central Europe. However, these early devices were so inaccurate that they were used mainly as gear-powered jewelry for curious nobles.

In 1657, watchmaking took a giant leap with the invention of the balance spring, also known as a hairspring. The balance spring is part of the escapement mechanism, a particularly complex and elegant part of a watch's movement. This invention reduced watches' margin of error from several hours a day to approximately 10 minutes. Today, world-class watchmakers note that the difference of a micrometer in the width of the balance spring can make the watch off by 30 minutes.

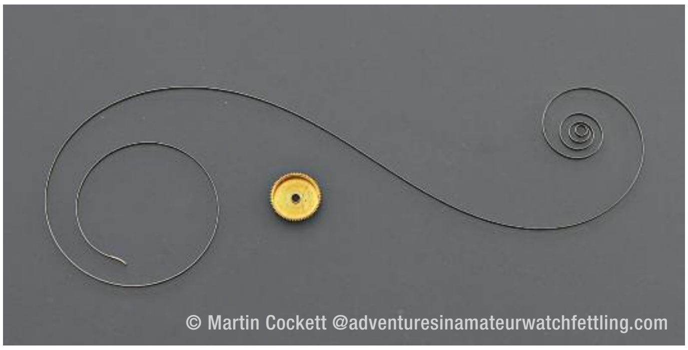
Even in the 18th century, the metallurgy of watchmaking was already a complicated affair. Watchmaker William Blakey wrote many thick books on handcrafting mainsprings. A quality mainspring in the 1780s could take days of highly skilled effort. Making watches by hand was time consuming and expensive, and therefore, it was mainly the rich who could enjoy timepieces.

As with many items now central to life in developed countries, the mass production of watches was made possible only through the mass production of steel. The industrial revolution was the first time in history that huge batches of iron could be produced with consistent properties. Pocket watches or pendant watches for women remained the dominant designs until World War I, which highlighted the utility of lightweight timekeeping devices. From then on, the wristwatch became the predominant design, and the rest is history.

Though watchmaking saw all kinds of wonderful developments throughout the centuries, mainsprings remained problematic. The carbon steel originally used for mainsprings lost significant elasticity and strength over time. As a result, the mainspring often failed far earlier than other parts of the watch. Mainspring repair was the number one reason for watch maintenance until the 1960s, when molybdenum-containing alloys and their special properties became a widespread alternative to carbon steel.

Saving time with moly

Several alloys have been specifically developed in recent decades to produce watches that run for greater stretches in



Mainspring in the barrel (left) and unleashed for cleaning (right). As mainsprings are wound with such force, they must be removed by a special tool to not injure the watchmaker!

between winding. How long a watch runs depends on its power reserve, or the amount of available mechanical energy stored in the mainspring. With these alloys, the most popular of which contain molybdenum, watches have longer and longer power reserves. The material for the mainspring must be very strong, elastic and tough. It also needs superior fatigue resistance to withstand years of cyclic loading. If the mainspring fails, it's not a simple replacement: a broken mainspring can damage or destroy the entire gear train of the watch, which is why today they are safely encapsulated in a barrel. Molybdenum-containing alloys offer a greater elastic limit and are less subject to breakage and permanent deformation than traditional carbon steel, making these springs last much longer. Because of its intricacy, mainspring manufacture remains a highly specialized craft – watchmakers almost always order them from one of the world's few producers.

Mainspring materials contain as many as 10 alloying elements, all of which affect the final properties of the spring. Molybdenum specifically helps with hardenability and strength, as well as ductility which are necessary for highly loaded tiny parts. It also improves the corrosion resistance of these alloys. The most popular mainspring alloy is NIVAFLEX®, a cobalt-nickel-chromium alloy with 4% molybdenum. Its very high tensile strength of 3000 MPa gives it incredible fatigue resistance. SPRON 510, with up to 10% molybdenum, and Bioflex®, with 2.5 to 4% molybdenum, are other popular choices for mainsprings.

The influence of magnetic fields can also negatively and substantially impact the accuracy of a watch. It is therefore important that watch parts are non-magnetic. Molybdenum alloying helps to make Nivaflex non-magnetic at temperatures typically encountered by a wristwatch. For this reason, sometimes other precision watch pieces like winding stems also necessitate molybdenum-containing alloys.

Balance springs, too, were traditionally made with carbon steel and suffered from similar problems as mainsprings. Like the mainspring, balance springs must be exceptionally hard and fatigue resistant, yet also be ductile and able to be machined to extremely minute tolerances. The best-known balance spring material is NIVAROX® CT, which contains as many as seven different alloying elements, all of which are decisive for setting the material properties, mainly a low temperature coefficient of elasticity. That in particular enables the timekeeping element, the watch's balance wheel, to keep better time. Although Nivarox does not contain molybdenum, at least one recent patent application exists for a molybdenum-containing balance spring that leverages the element's unique properties. Molybdenum even comes to the aid of watches in chemical form: several mechanical watch brands use molybdenum disulfide lubricants on gears and in the mainspring barrel to keep the timepiece running smoothly.

Mechanical watches embody centuries of ingenuity, artisanship and curiosity. Though many feared that these works of art would disappear in the wake of battery-powered quartz watches – and now smartphones – the mechanical watch industry remains vibrant. Take for instance the flamboyant watch enthusiast community on YouTube; evidence that the elaborate movements continue to enrapture successive generations of watch fans worldwide. Their tick and movement calls attention to the passage of time in a way the smartphone cannot. Above all, mechanical watches harken back to an era where time actually seemed to run slower. Molybdenum in their most essential components helps keep the nostalgia, tradition and pursuit of mechanical perfection alive in a digitized age. (KW)

Many thanks to Alberto Bracchi, Vacuumschmelze GmbH and Alberto Sicco, Générale Ressorts for their valuable input.

IMOA news

IMOA appoints new Secretary-General

IMOA appointed Eva Model as its next Secretary-General, effective September 1st, 2021. Eva succeeded Tim Outteridge, who announced his retirement in September 2020.

Eva has a detailed knowledge of the Association, having previously served on the Executive Committee and as Vice-President and President. Her wealth of experience of the molybdenum industry includes over 20 years at Rio Tinto, culminating in her position as General Manager, responsible for the sales and marketing of all products from the Kennecott Utah Copper mine and processing facilities in Salt Lake City, including copper cathode, molybdenum, rhenium, precious metals and other by-products.

Eva's recent experience of leading a trade association in her previous role as General Manager of the Minor Metals Trade Association, coupled with her molybdenum industry knowledge, makes her the ideal person to drive IMOA forward.

A warm welcome to Eva Model, IMOA's incoming Secretary-General.

On her appointment, Eva said: "I'm honored to have been appointed as IMOA's next Secretary-General. The Association has long been the independent voice of the molybdenum industry, and I look forward to working with IMOA's members to continue to raise awareness and promote the important role molybdenum plays in our modern world."

Over the past 13 years during Tim's time as Secretary-General, IMOA achieved many notable successes. In the area of environment and human health, an extensive and unrivalled repository of knowledge about the effects of molybdenum has been compiled. This repository was deployed for the registration of the 12 REACH substances and the continual, diligent updating of the substance dossiers as required by ECHA. IMOA achieved the recognition and endorsement of its soluble salts database by the OECD and ensured that regulators around the world have access to the data through direct engagement and the publication of peer-reviewed, scientific papers. This effort has and will continue to facilitate fair and appropriate regulation of molybdenum and to maintain access to markets. While IMOA's work in Market Development has contributed to the growth of molybdenum use across stainless and alloy steels, in architecture, building and construction, infrastructure, automotive, mechanical engineering, energy generation, processing industries and other sectors. The new structural stainless steel standards due for publication later this year will add to this successful track record.

Tim said: "I consider it a privilege to have served as Secretary-General for the last 13 years. You will be the judge, but I hope to be leaving IMOA in a better place than when I arrived. I have been fortunate to enjoy the support of our Presidents, an enlightened and thoughtful Executive Committee and the membership, for which I am most grateful."

Stainless flexible service lines – the fit and forget solution to water loss

IMOA continues to work on strategically important projects that promote the sustainability credentials of molybdenum.

One initiative that could have an extremely positive impact on the environment is the stainless steel water service line project. Water utilities worldwide lose an estimated 25–30% of treated drinking water through leaks in their distribution network, with the majority of leaks occurring in the service line between the water main and the water meter.

Over the last 40 years, across millions of connections in some of Asia's largest cities, service lines made from stainless steel partially corrugated tubing (SPCT) have dramatically reduced water loss, and the number of repairs required.

As part of Team Stainless, IMOA has successfully generated interest in the stainless steel service lines within a number of new global regions through webinars, presentations, videos and brochures.

The benefits of stainless steel SPCT were also featured recently in a live webinar hosted by the International Water Association (IWA) Water Loss Specialist Group and presented by Dr Nicole Kinsman, IMOA's Technical Director. The webinar included case studies from some of Asia's largest cities, demonstrating how stainless flexible service lines offer water authorities a long-lasting and cost-saving solution to reducing both water loss and repair cases.

These molybdenum-containing tubes are cost-effective, robust and sustainable, ensuring the delivery of safe water supplies for generations to come.

The webinar is now available on-demand from the IWA Water Loss Specialist Group YouTube channel. Stainless Flexible Service Lines. A durable, fit-and-forget solution to water loss - Nicole Kinsman - YouTube

Further information on the stainless flexible services lines can be found on the Team Stainless YouTube channel, which contains videos on the installation process, and can be downloaded from the Team Stainless website.

IMOA members benefit from discount at the CRU Ryan's Notes Ferroalloys conference

IMOA members are entitled to a 15% discount off the delegate fee to this year's Ryan's Notes Ferroalloys conference. After a year where most events have been online, this conference will take place in-person at the JW Marriott Grande Lakes in Orlando, Florida, USA from the 24–26 October. Sign up and get the discount Home | CRU Ryan's Notes Ferroalloys Conference 2021 (crugroup.com).

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Cover photo: The Jakob factory's stainless steel façade consists of two layers of symmetrically inclined cables which support nine levels of planter frames with cable clamp connections. © Oki Hiroyuki

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