INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

Moly rescues a lady in distress

Since its dedication in New York harbor on October 28, 1886, The Statue of Liberty has become one of the world's best-known sculptures. However, after nearly 100 years in the aggressive marine environment, galvanic corrosion between the iron framework and the copper skin caused major structural deterioration. Molybdenum-containing stainless steel played a crucial role in restoring this iconic landmark.

The Statue of Liberty was conceived and created by the famous French artist Frédérick Auguste Bartholdi and structurally designed by Gustave Eiffel. It was constructed using some of the most advanced techniques of its time and presented as a gift to the people of the United States from the people of France.

The original structure of the 46-meter statue had a puddled-iron framework of a central pylon, secondary framing and armature bars. The central support pylon had four cross-braced legs with a double-helix staircase rising through its center. The secondary iron framework connected the 1850 puddled-iron armature bars to the pylon. The armature bars supported the copper sheets and allowed movement. About 1,500 U-shaped copper saddles connected the armature to the 73-tonne, 2.4-mm thick copper envelope. This inspired structural design allowed the envelope to flex and expand, and avoid cracking due to heat, cold, and wind.

The restored Statue of Liberty raises her torch to greet new arrivals to New York City and the United States. © Rudy Norff

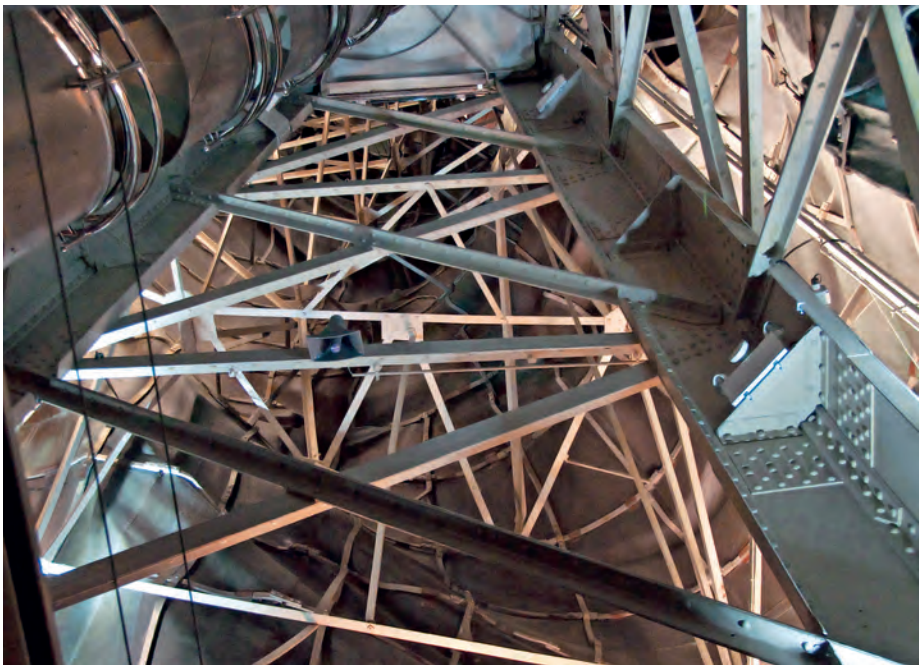
When dissimilar metals are connected, galvanic corrosion can occur. When such a "galvanic couple" is exposed to an electrolyte, e.g. moisture, salt and pollutants, the more stable metal will be protected and the other metal will corrode at an accelerated rate. The greater the difference in surface area between the two metals, the faster corrosion will occur. Copper is more stable than iron in salt-water environments, so the statue's design harbored potentially serious corrosion problems.
Eiffel and his structural engineer Maurice Koechlin understood and anticipated the problem, and electrically isolated the materials using shellac-impregnated asbestos pads. They believed that any corrosion would be apparent upon close inspection, and could be dealt with when found. However, structural and design changes over time allowed more water to enter the structure than anticipated. The interior was therefore painted with coal tar in an attempt to seal the seams. Due to the failure of the asbestos barrier the secondary framework in the arm support structure and much of the sculpture's armature had been replaced by 1938. Over the years leading up to the statue's refurbishment in 1984–1986, its interior was painted at least ten times for cosmetic and protective purposes. Only in 1980, when the statue was inspected carefully after it had been scaled by political protesters, was the extent of the damage to the copper envelope and structural supports discovered requiring extensive rebuilding and repair.

Severe corrosion of the iron armatures had produced rust that expanded (due to its greater volume than the iron) and damaged the copper sheet, requiring replacement of all but a few bars in the foot. Molybdenum-containing Type 316L stainless steel was chosen for this job because of its excellent corrosion resistance in marine air and because there is minimal galvanic corrosion effect with copper in this environment. An additional advantage of this choice was that the coefficients of thermal expansion of Type 316L stainless steel and copper are the same, eliminating mechanical stresses due to temperature variations. Teflon® was used to electrically isolate the metals from one another as an additional measure of protection, even though the risk is low.

There had also been significant deterioration of the secondary framework. The restoration team replaced much of it with a new high-strength secondary framework of highly corrosion resistant, molybdenum-containing duplex stainless steel (UNS S32550). The new framework is attached to the central pylon and supports the Type 316L armature. The sections of the original secondary framework that remained were cleaned and coated with a zinc primer and epoxy topcoat. These layers protect it from ›

corrosion and help to electrically isolate the iron from the stainless steel. Type 316 stainless steel was also used to replace the circular stair treads, for emergency elevator components, and for a redesigned pedestal stairway.

As a result of this remarkable restoration project, Lady Liberty is now well into her second century guarding New York harbor and welcoming those who arrive. Thanks to molybdenum-containing stainless steels, she should continue her greetings well into her third century. (Catherine Houska, John Shields)



Looking up through the central pylon the intricate detail of the unique structure built to support the statue's façade can be seen. © Mike Renlund