HISTORICAL PRESERVATION

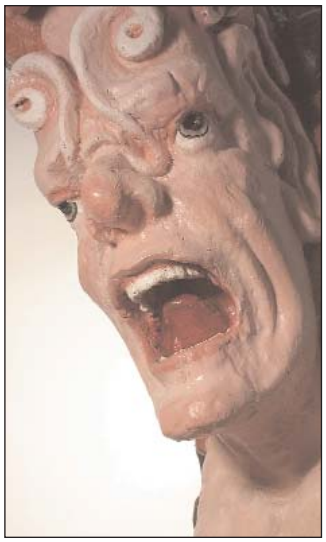
Sweden Launches a Desperate Bid to Save Famous Warship

Ill-fated from the start, the *Vasa*, the pride of the Swedish navy, ignominiously keeled over and sank on its first voyage in 1628, drowning a quarter of the 150 sailors on board. The demands that King Gustavus Adolphus had made on the shipbuilders overwhelmed the technology of the day, as a pair of gun decks mounted with 64 cannons destabilized the narrow vessel. Soon after firing its farewell salute, the *Vasa* heeled, water rushed into the open gun ports, and in minutes it was lost—but not gone forever.

More than 3 centuries later, a similar lack of technical know-how threatens to finish the job. Sulfuric acid has infused the hull of the wooden ship, one of the largest ever to be salvaged intact, and is dissolving it from the inside out. The acid is produced by oxidation spurred by thousands of metal bolts inserted into the *Vasa* to hold it together after the 1210-ton vessel was raised from Stockholm harbor in 1961. Next month, scientists will mount a last-ditch attempt to prevent the ship's disintegration.

In the decades after the *Vasa* went down, entrepreneurs used diving bells to recover most of the bronze cannons. The ship then faded into obscurity until 1956, when amateur shipwreck-hunter Anders Franzén—using a rowboat and homemade sounding device—located it after a several-year search. The *Vasa* was in astonishingly good shape, with sails, rigging, and the flamboyant carvings adorning the prow and stern still intact. After the Swedish navy helped raise the ship, conservators spent nearly 2 decades meticulously preserving it. Several hours a day for 17 years, they hosed the hull down with a mix of water and polyethylene glycol to gradually stabilize the structure. The restored *Vasa* was unveiled in 1990 in a spectacular museum in Stockholm.

Three years ago, however, museum staff began to notice alarming white deposits on the vessel's surface. An investigation led by chemist Magnus Sandström of the University of Stockholm found that sulfuric acid is accumulating in the ship's beams and attacking the *Vasa* by eating away the cellulose and forming crystals that expand and may create fissures in the wood.



Cry for help? *Vasa* sculpture.

During the 333 years that the *Vasa* lay at the bottom of the harbor, Sandström and his colleagues hypothesize, hydrogen sulfide produced by anaerobic bacteria in the polluted and oxygen-poor depths permeated the vessel. The hydrogen ions were gradually stripped away, depositing elemental sulfur in the wood. After the *Vasa* was exposed to air in 1961, oxygen began to react with the sulfur to form sulfuric acid. The restoration effort had unwittingly abetted this process by peppering the ship with an iron catalyst: the steel bolts holding it together.

In hindsight, the decision to use steel "was a bit unfortunate," says Sandström. The conservators, he says, had done their best to prevent corrosion, by fashioning the bolts from galvanized steel covered with an epoxy. "They couldn't afford stainless steel," he says, which would not have catalyzed the reaction. In any event, Sandström says, they could not have anticipated the presence of so much acid in the wood that would quickly dissolve the epoxy and zinc cladding of the bolts.

Now a new group of experts, selected in June in a competition sponsored by Sweden's National Maritime Museums, is joining forces with Sandström to rescue the *Vasa*. They must address a few key questions first. For one, it's unclear whether bacteria—either colonies in the ship before it was raised or those that have invaded it since—are also spurring the sulfuric acid reaction. The team, with researchers from Sweden, Denmark, and the U.K., also intends to explore whether the polyethylene glycol sprayed during the restoration influences acid formation.

The bugbear, though, is iron. There are two challenges: replacing the bolts and removing the iron ions that have diffused into the cellulose. The plan is to swap in carbon fiber–based fasteners for all accessible bolts, but that unavoidably will leave at least 4 tons of iron in the hull.

Purging the iron ions without damaging the cellulose, meanwhile, is not so easy. Chemist Ingmar Persson of the Swedish University of Agricultural Sciences in Uppsala has tested a chelating agent developed for alkaline soils on samples of *Vasa* wood. The compound, similar to the common chelator EDTA (ethylenediamine tetraacetate), seems to be able to bind the iron and neutralize acid. But applying this method to the *Vasa* could take years. "We need to have something [that works] a bit faster," Persson says.

Under siege. The museum housing the *Vasa* will remain open as researchers strive to rescue the stunning 17th century warship from the acid eating away its hull.

His team will test various preparations at a range of temperatures to try to hurry along the chelation process. Still, the compound's long-term effects on cellulose are unknown, says Persson, "and we certainly don't want to make things worse."

Moreover, it would be impossible to bathe the 69-meter-long ship in chelating solution, says Ingrid Hall Roth, head of conservation at the National Maritime Museums. Dismantling it would be a last resort. Everyone agrees, though, that a way forward must be found quickly: It's unclear how much time the researchers have before the ship is damaged irreversibly.

Any fix the project devises will be welcomed by conservators around the world. Most wrecks salvaged in recent decades also suffer from less severe sulfur damage, Sandström says, including the *Mary Rose*, a 16th century British warship on display in Portsmouth, and the *Batavia* in Fremantle, Western Australia. The would-be saviors hope their solution will be kinder than the resurrections of the *Vasa* and other sunken vessels have proven to be. —GRETCHEN VOGEL

CREDITS: (TOP TO BOTTOM) HANS HAMMARSKIÖLD/THE VASA MUSEUM; STEFAN EVENSEN/THE VASA MUSEUM