The Reconstruction of Helen Smitton - Methods Employed to Overcome the Effects of Corrosion – By Malcolm Brown

Boats and ships, like other working objects such as engines, locomotives and aeroplanes do work in the true engineering sense which require constant maintenance and repair. They are also capable of inflicting injury. Those who reconstruct and conserve such working objects are aware of the responsibility this imparts and the impact upon the conservation methods employed, the materials used and upon changes to the original structure. In conserving or reconstructing a working vessel I have five things uppermost in my mind – the safety of those who come in contact with the vessel, conservation of the vessel's structure with minimum intervention, long-term sustainability, interpretation and the environmental impact of my work.

Boats are complex objects with each structural piece of timber or metal mutually dependent on others to create overall strength. By the very nature of a vessel's shape, compound curves are created by bending and twisting metal and wood which creates tensions within the structure. Built in layers, component No.1 is overlaid by component No.2 which is again overlaid by component No.3, and so on. This is where work on a vessel gets interesting as it is often the case that the sandwiched component is the one that requires attention.

Changes to a working vessel are inevitable during reconstruction, not only to conserve the fabric of the object for future generations but also because adaptations are necessary due to a vessel's change of use. Few people appreciate that how a vessel is operated, housed or moored affects her sustainability. As an example, a wooden trawler going about the business for which she was designed has her wooden decks constantly awash with seawater and fish oil and, being on the move, well ventilated below decks. All this is good for a wooden vessel, but if she has a new largely sedentary life in private hands her deck timbers will be at risk from the sun and rain causing rot, and her interior will, similarly, be at risk from lack of ventilation. Her use has changed; therefore changes to the way she is managed and possible changes to her structure have to be considered. Even a regular bucketful of seawater thrown on a wooden deck can have a positive impact on preventing rot. How she is crewed and moored can subtly affect the deck arrangement of a vessel as dictated by shortened crew numbers and marina pontoons.

Modern safety standards and expectations dictate that changes are inevitable. A hundred years ago most vessels did not have lifelines, cathodic protection systems or reliable bilge pumps and engines. This inevitably brings conflict and dilemmas and it is important to recognise where the conflicts lie, to come up with appropriate solutions, to record those changes and to be prepared to justify the options and final solutions chosen.

Fig.1 Helen Smitton arrives at St Abbs, Berwickshire, April 1910

Helen Smitton is a Royal National Lifeboat Institute (RNLI) non self-righting motor/sailing/pulling lifeboat built in 1910 by The Thames Iron Works, Blackwall, who half a century earlier had built *HMS Warrior*. She is being reconstructed near Dale, Pembrokeshire. *Helen Smitton* was one of the first lifeboats built with an engine and is the last survivor of her type. She was built at a time of great change and debate concerning whether lifeboats should be self-righting or fitted with engines. The RNLI and lifeboatmen of the past, who were generally men who earned their living from the sea tended to be a conservative lot, resistive to change.

The vessel is of double diagonal construction in that two relatively thin layers of Honduras mahogany hull planking are run at roughly right angles to one another. The second layer is bedded onto the first with a coating of calico[1] and white lead paste[2] before the two layers are copper riveted together. Other timbers used in her construction are Canadian rock elm, teak and English oak. The fastenings employed in her construction are copper, naval brass, bronze, wrought iron, cast steel, cast iron and mild steel.

Helen Smitton has survived for over one hundred years because of superior craftsmanship and high quality timber, both of which were readily available prior to the First World War. She was built for a service life of 25 years, and in that time spent most of it between ‘shouts’ in a cosy tin shed at the top of the St Abbs slipway where she was pampered by her crew of herring fishermen. The construction methods used and materials employed were perfectly satisfactory for her role during that period; the craftsmen who built her would, however, be somewhat surprised that a working vessel had lasted over 100 years. When sold out of service by the RNLI in 1936 a fundamental change took place in that she was kept, like most vessels, out in the open where she was now under constant attack from the elements.

She suffers from a number of major problems to her main structure caused by the choice of her original materials, poor maintenance and amateur modifications and repairs. By far the greatest problem that affects the hull is caused through bi-metallic corrosion to most of her iron and steel components and fastenings, and associated degradation of adjacent hull timbers below the waterline.

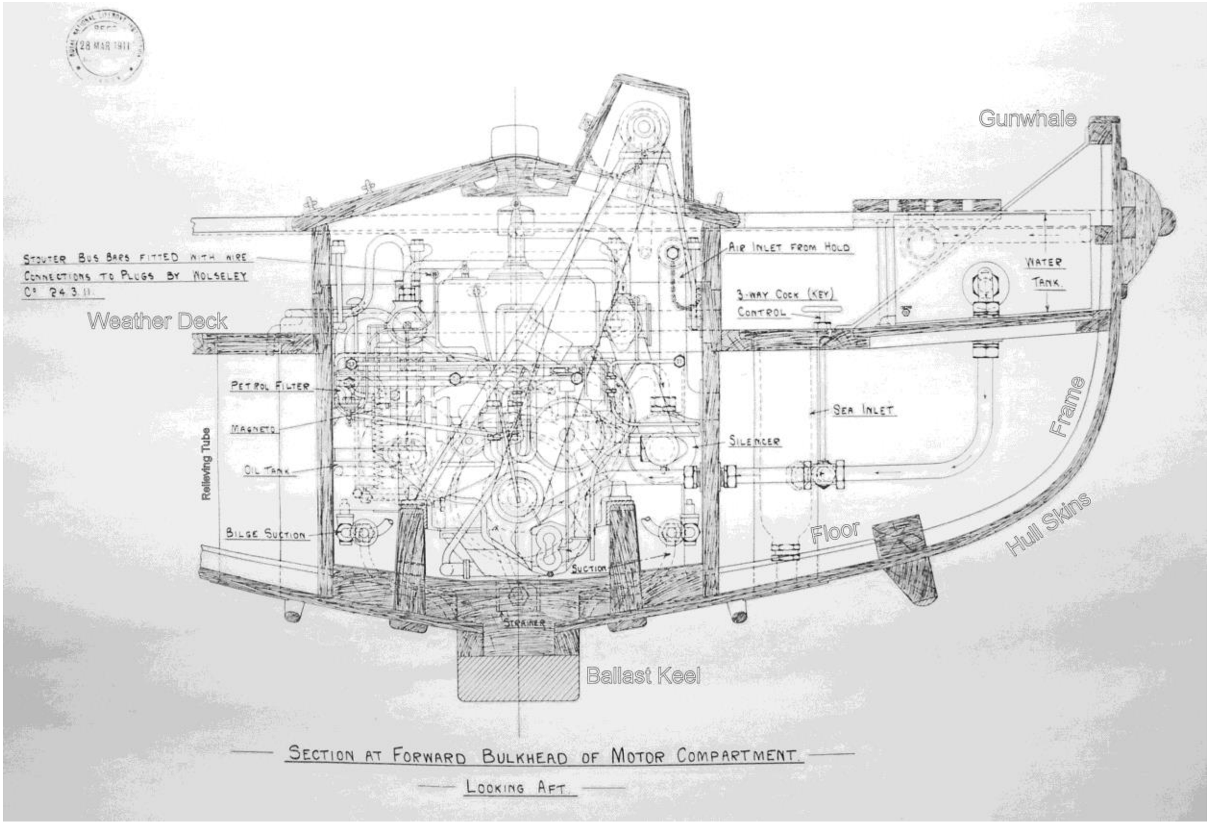

Fig.2 Cross-Section of the hull at the engine compartment.

The effects of saltwater degradation are clearly visible throughout the vessel where dissimilar metals have been employed at the same location, such as between the steel floors and their fastenings of bronze. The bronze and copper throughout the vessel has remained in good condition whilst the steel, particularly in the bilges where seawater was present, has wasted away. The hundreds of naval brass screws that also secure the hull skins to the centre-line structure are in remarkably good condition and in most cases can be withdrawn cleanly, but under a magnifying glass they show pitting, so cannot be trusted. The pitting is most likely caused through de-zincification.

> 'Dealloying is a corrosion process (occurring in seawater) in which the active metal is selectively removed from the metal, leaving behind a

weak deposit of the more noble metal... In the de-zincification of brass, selective removal of zinc leaves a relatively porous and weak layer of copper and copper oxide' [3]

These fastenings are being replaced with Silicon bronze screws.

As any surveyor knows, corrosion can be more acute near the waterline of a vessel due to the different concentrations of oxygen above and below it. The surface of different metals, but also of the same metal - as in the case of a steel ship - can corrode at different rates dependent upon whether they are acting as a cathode (above the waterline), or an anode (below the waterline).[3]

Fig.3 View of the mild steel floors on the starboard side of the propeller tunnel. Most of these floors disintegrated when tapped with a hammer.

Fig.4a Fastenings removed from the hull. The items to the left indicate how fittings that are less noble, steel and iron, can corrode whilst their fastenings of copper and bronze remain intact. The large bolt is one of ten that secures the ballast keel to the hull. The mid section has corroded away. The four fastenings, bottom right, are wrought iron bolts removed from the gunwhales.

Fig.4b Further examples of corrosion. The bronze coach screw in the centre of the photograph and the naval brass woodscrew above it is a good example of fastenings that on first inspection appear to be ferrous but are actually coated in oxide from neighbouring corroded steel.

Fig.5 The floors and deck support shown in Fig.3 now removed and replaced with mild steel plate coated with epoxy primer. The threaded end of the new galvanised bolts can be seen. Once the new plates have been welded to the original remaining sections around the tunnel, they will again receive numerous coatings of epoxy primer, undercoat and topcoat.

Fig.6 View from further forward, starboard side. The dark area to the right is the outer surface of the engine compartment. The circular disks blank off the hull skin end of the relieving tubes. These will eventually be through-bolted to the hull. Between the disks the new steel outboard ends of the engine compartment floors can be seen through-bolted to the frames and hull skins. The large section timber running fore and aft is the bilge stringer.

In 1910, corrosion between dissimilar metals in salt-water was known about by the builders but not fully understood.

As early as 1867, in *Engineering*, when discussing Ironclads, it was remarked that :

> '...the objection to composite ships is that they are not as cheap or as strong ... but a still greater objection lies in the fitting of planks to the iron frames by any expedient which will not involve corrosion by galvanic action. If the wood is bolted to the iron by iron bolts, the coppering, when applied, will quickly waste these iron bolts, so that they will become unsafe; whereas, if the attachment is made by means of copper bolts, the bilge water within the ship will cause the copper nuts quickly to corrode the iron frame' [4]

When built, *Helen Smitton* was fitted with two large zinc plates close to the propeller tunnel to act as sacrificial anodes but they were poorly bonded to the metals they were designed to protect which made them totally useless. The same original anodes have been removed from the vessel; they are almost totally intact which indicates their failure.

> ‘Bimetallic corrosion occurs when two metals, with different potentials (voltages), are in electrical contact while immersed in an electrically conducting corrosive liquid (seawater). Because the metals have different natural potentials in the liquid, a current will flow from the anode (more electro-negative) metal to the cathode (more electro-positive)’[5]

From the table below it can be seen that where steel components, such as the floors and knees have been fastened with copper or bronze, a difference in potential (voltage) is present, so current will flow causing corrosion to the least noble - steel. In wooden vessels, if the potential difference and current is high, it is sometimes possible to find distinct tracks across the surface of the wood where current has flowed over a long period.

Table 1 Galvanic Series of Helen Smitton’s Metals in Seawater[4]

	DC Volts with reference to Ag/AGCI cell	
Zinc (cathodic protection anode)	-1	Least Noble (corroded metal)
Mild Steel	-0.6	
Cast Iron	-0.6	
Copper	-0.5	
Naval Brass	-0.4	
Bronze	-0.4	Most Noble (protected metal)

Apart from the obvious damage to the metal that is less noble, such as steel, what is noticeable is the change in the integrity of the wood immediately surrounding the more noble fastenings such as copper or bronze. The fastenings themselves have been protected by the less noble metal which, as a result, corrodes. The wood, however, has shrunk away from the fastening leaving it loose and in some cases the wood fibres have broken down leaving, in the case of mahogany, a furry texture. The wood often splits in the direction of the grain. Baker, when speaking about the corrosion of fastenings in wood and cathodic protection stated that there was:

> ‘...common evidence of alkaline conditions around a cathode in wood ... After a number of years the accumulation of alkali will weaken the wood... The vessel can literally ‘stew in its own juices’ until the wood disintegrates near the protected metal. It probably requires more than 10 years to produce conditions that can cause much loss in strength to the wood, but severe strength loss has been noted in wooden vessels 20 years old.’[6]

The most time-consuming job as a result of the conditions mentioned above has been to repair and realign about one hundred large fastening holes passing through the hull. Because of the long-term deterioration of the fastenings and the mild degradation of the surrounding timber, the frames, floors and hull skins no longer lined up and in most cases the stopping (filler) covering the fastening heads is loose or missing.

The degradation at each hole was in most cases mild but the overall effect weakened the hull. I could have overcome this problem by replacing much of the hull planking with another species of timber, as high class mahogany is no longer available, but this would have caused considerable unwarranted intervention and loss of original structure. Applying a method I have successfully used in the past, each hole was cleaned back to sound timber, coated with West System[7] 105 epoxy resin with 205 slow hardener and then completely filled using the same mix of resin/hardener with colloidal silica filler, mixed to a thick paste. Once set, the holes were re-drilled and new fastenings fitted. The original floor fastenings had countersunk heads but I took the decision to replace them with domed heads (coachbolts) which covered a wider contact area, overlapping the localised repairs mentioned above. In later years the RNLI used the same fastenings in high stress areas. This method of repair has the added advantage that each fastening now becomes largely electrically isolated from the surrounding timber by the epoxy resin which cuts down on stray electrolytic currents.

Fig.7a A close-up view of one of the 3/8” diameter floor fastenings being withdrawn, showing the secondary effect of bi-metallic corrosion.

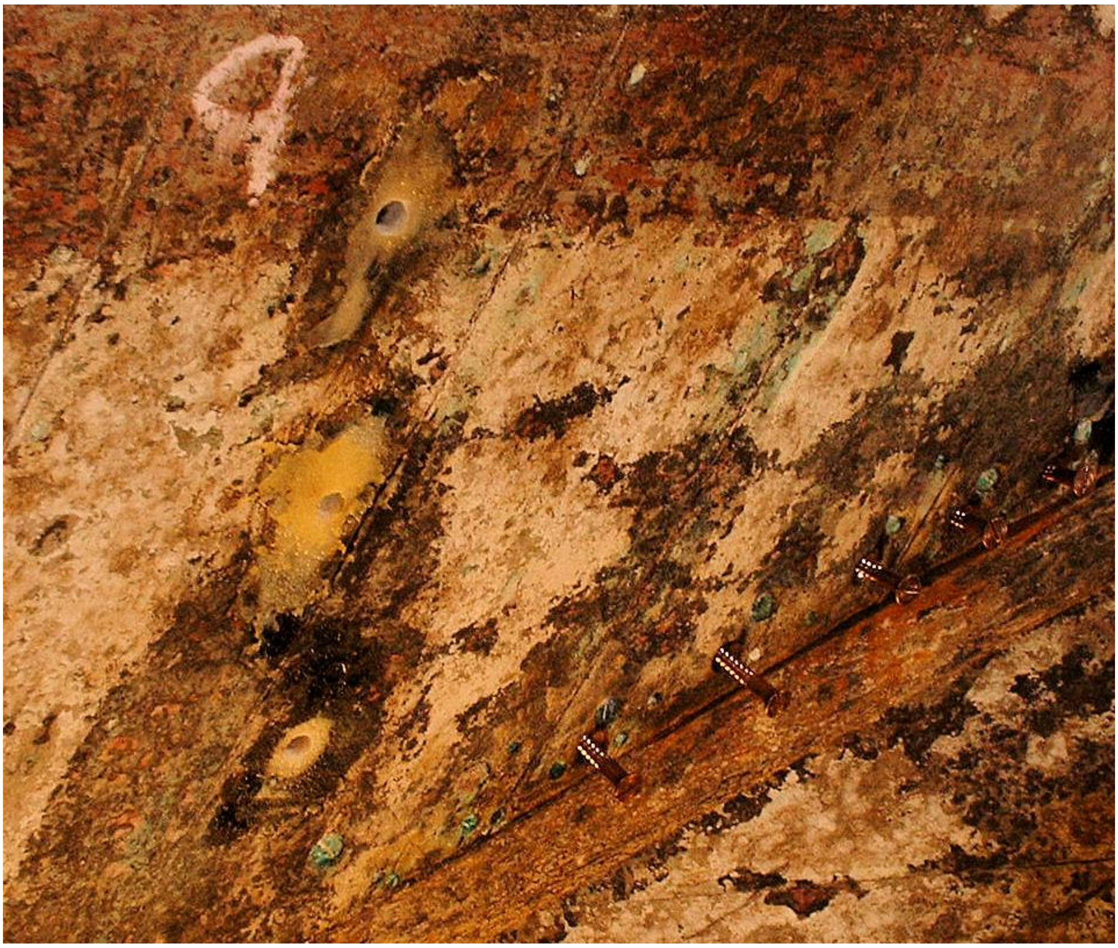

Fig.7b The re-drilled floor fastening holes having first been filled with epoxy resin/filler. The silicon bronze screws are there to replace the hood end naval brass screws that were pitted.

Fig.7c The floor holes prepared to accept the new galvanized coach bolts. To ensure the bolt heads have a good seating, the area under each head has been flattened off using a modified flat drill bit with a central guide having the same diameter as the fastening.

Fig.7d The new fastenings in place. Each bedded down with white lead paste and a twist of caulking cotton under the head.

To increase the sustainability of the vessel changes have been made to the fastenings used. Cast steel floors and wrought iron deck knees were fastened with either copper or naval brass. Where these have been replaced, galvanised steel has been used to reduce galvanic action.

The gunwhales were fastened to the hull skins with ½" wrought iron bolts. On the face of it the number and size seamed disproportionally high but the gunwhales hold the sockets for the rowlocks, therefore the power of ten men rowing is transmitted to the hull via these timbers. Wrought iron, when confined in timber, corrodes beyond all recognition. It does, in effect, burst to twice its normal size and often splits the timber it is passing through. The fastenings cannot be driven out without destroying the timber so the whole length of the timber has to be replaced which, again, causes major disruption and loss of original fabric. To overcome this problem I use my “apple corer” method where a hole-cutter, held in a temporary guide without its central drill, bores out the timber just beyond the extent of the corrosion. The fastening is withdrawn and the hole plugged with a similar species of timber. A new fastening can then be fitted.

Fig.8a Core of timber around the corroded wrought iron fastening bored out with the help of a plywood guide.

Fig.8b Corroded wrought iron fastening withdrawn

Similarly, the cast steel floors crossing the engine room sole had totally eaten away at their outer ends. To replace them would have meant the removal of all the engine room bulkheads and the two teak engine beds that ran almost the whole length of the vessel. Driving out the long fastenings holding the beds to the hull would have inevitably destroyed both. Fortunately the centre sections of the floors, although mildly corroded, were sound, so the decision was taken to cut off the floors in the engine room and weld in new lengths to replace those corroded. The fastenings holding the original sections were then replaced.

The methods adopted are very time-consuming and laborious but without it Helen Smitton could not have been conserved for future generations without considerable loss of original fabric at enormous financial cost.

Helen Smitton will have zinc sacrificial anodes fitted directly to the ballast keel and rudder ironwork and anodes fitted within the propeller tunnel which will be electrically bonded to the engine and propeller shaft. With the reduction of dissimilar metals and a well designed cathodic protection system in place, corrosion will be drastically reduced.

As stated earlier, changes are inevitable. When built, Helen Smitton was filled below the watertight deck with air cases, sealed wooden boxes each averaging around 1cu.ft., filling every available space rather like a Rubik's Cube, each box being tailored and labelled for its unique location. The idea being that if the boat sustained a breach to the hull, the boxes would keep her afloat. Those boxes, apart from six, are missing. With the belief that this vessel was, in effect, unsinkable and because she was always fully manned when afloat, liberties were taken with her design and operation that in today's risk-averse world is not appropriate. One such case is her relieving tubes, nine thin-walled copper tubes 6in in diameter connecting the weather deck directly with the sea below the waterline without any means of closure. These tubes were designed to shed water from the deck very quickly. With the lack of air cases and the knowledge that this set-up would be considered unacceptable to regulatory authorities - as the vessel would sink very quickly if one failed - the apertures in the hull have been blanked off with the deck drains now diverted to new tanks where the water is collected and automatically pumped overboard.

With all the technical problems that arise during reconstruction, there is a balance to be struck between using modern materials in small quantities to preserve original fabric. I do not, however, use modern materials when traditional materials such as white lead paste, used in her original build, are still available.

Minimum intervention to conserve as much of the original structure was employed. As an example, Helen Smitton had two isolated patches of rot in the two bilge stringers, port and starboard. The bilge stringers, which are approximately 150mm x 60mm in section, are about 10m long. To replace the stringers would mean the removal of many large fastenings and a watertight bulkhead; a major disturbance to the structure, loss of original fabric and many hours of costly work. The solution was to cut out the rot, scarf in new short sections and refasten. Being short sections they had to be glued and, being major structural members, epoxy resin glue was the best solution. Reversibility, where great strength is required in a hostile environment, is not yet possible. I take the view that such repairs to a working vessel form part of its history and recorded in the same manner as previous repairs that come to light during her reconstruction.

It is hoped that Helen Smitton will be re-launched in "as-built" condition in 2015.

<u>Footnotes</u>

1 Unbleached cotton cloth

2 Lead carbonate and linseed oil paste.

White lead paste is present throughout vessels of this age, used mainly to bed one component onto another. It is poisonous and should be treated with caution. The author knows of no specific safety guidelines for white lead paste but a guide is published by English Heritage concerning high content lead paint. http://www.english-heritage.org.uk/professional/advice/advice-by-topic/buildings/maintenance-and-repair/paint-legislation-historic-buildings/

Where a large quantity of white lead paste is disturbed, creating dust, such as when removing a ballast keel, I wear a Scott Safety half hood powered respirator with appropriate filter.

3 A detailed description of boat construction is outside the limit of this article but two books are recommended for further reading:

Robert M. Steward, *Boatbuilding Manual* (International Marine Publishing, 1970)

Howard Chapelle, *Boatbuilding* (George Allen and Unwin, 1941)

4 E.McCafferty, *Introduction to Corrosion Science* (USA: Springer, 2010), 88.

5 National Physics Laboratory. *Guides to Good Practice in Corrosion Control.* **www.npl.co.uk/upload/pdf/bimetallic_20071105114556.pdf** accessed 28/4/13

6 C. Young, *The Fouling and Corrosion of Iron Ships: Their Causes and Means of prevention* (The London Drawing Association, 1867).

7 J.R. Davis, Ed., *Corrosion – Understanding the Basics* (The Materials Information Society, 2000)

8 Various sources

9 A.J. Baker, *Degradation of Wood by Products of Metal Corrosion* (US Department of Agriculture, 1976).

10 Wessex Resins & Adhesives Ltd., Cupernham House, Cupernham lane,

Romsey, Hants, SO51 7LF, UK

Tel: + 44 (0) 1794 521111

The Author

Malcolm Brown is a freelance Boat & Ship Conservation Specialist who advices museums, trusts and private clients on the conservation, management and interpretation of historic vessels. From a shipping family, he was initially trained as an engineer within heavy industry and in subsequent years worked as an engineer and consultant within the steel, marine (seagoing) and power industries. He later studied Boatbuilding and Design and went on to become a Yacht Surveyor and Code of Compliance Surveyor, with particular expertise in historic vessels. To obtain a deeper understanding of conservation and heritage matters he obtained a Masters Degree in Industrial Archaeology at Birmingham University (Ironbridge) in 2000. He is a part-time university academic and owner of a Watson 46’9” lifeboat registered with NHS, and built in 1957.