The Cutty Sark,

The Trials and Tribulations of a Restoration Project

(Cutty Sark1.jpg)

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Contents

Summary

This paper covers the work being done on the clipper Cutty Sark to determine exactly the state of the ship's structure and the methods available to ensure this structure survives for the foreseeable future.

It covers the findings of a very complete survey carried out in 1997, the on going trials and experiments all directed at specifying the work needed to refurbish the ship, ranging from electrolytic treatment of corroded metals to the search for a politically suitable source of hardwood for the upper deck. From the high tech, finite element analysis of the ship's structure to the tested and traditional techniques of the shipwright.

The paper covers a lot of work already completed, but it is as nothing, however, compared with the work to be done once the team get the funds. But it is to be hoped that, as a result of all this work, the Cutty Sark will still be seen over the roofs of Greenwich for some time to come.

1. Introduction

This paper covers the work being done on the clipper Cutty Sark to determine exactly the state of the ship's structure and the methods available to ensure this structure survives for the foreseeable future.

It covers the findings of a very complete survey carried out in 1997, the on going trials and experiments all directed at specifying the work needed to refurbish the ship. It is intended to be a fairly wide ranging paper, detailed descriptions of some of the techniques are available from the various papers, publications and conservation documents referenced below.

The author's personal involvement with the ship goes back several years, whilst employed by Three Quays Marine Services, and started in earnest in 1995 with the management of a full survey and the technical support for the owner's unsuccessful application to the UK's Heritage Lottery Fund (the lottery) for a large sum of money to make good the structure.

This paper will also try to cover some of the reasons for that lack of success and the steps that have been taken to get the accurate costings that have gone into the latest application to the lottery.

Although part of the overall restoration project, this paper will not cover the civil engineering work that has gone on in parallel. Suffice it to say that there are likely to be some very innovative ideas proposed for the support of the vessel and its visitor infrastructure.

2. History of the Cutty Sark

The sailing vessel Cutty Sark owes her existence to the Chinese tea trade. Although tea had been exported to England since the 1660s, the nineteenth century manifestation of the trade was the result of the forcing open of the Chinese ports to Western ships, achieved by way of the infamous Opium Wars.

The Treaty of Nanking signed in 1842 opened Canton, Amoy, Foochow, Ningpo and Shanghai to free trade, while the Treaty of Tientsin signed in 1858 after the second Anglo-Chinese War opened up ports on the Yangtze. The most important of these was Hankow, 586 miles up the Yangtze.

The result was an explosion in the amount of tea exported. In 1834 Britain imported 33.6 million lbs of tea; the following year it increased to 44.3 million lbs. With the repeal of the Navigation Laws (which allowed only British ships to unload at British ports) in 1849, this rose to 55.5 million lbs.

The demand for tea never seemed to be satisfied – merchants could sell without difficulty. However, it became the fashion to drink the freshest tea and particularly from the first ship to arrive with that season's cargo. This therefore created a demand for ever-faster ships, not ones with enormous carrying capacity.

This was to result in the clipper ship, a form originally developed in the United States but copied and improved upon by the British. Over 80 clippers were built in the short period between 1853 and 1870, although never more than sixty at any one time.[1]

[1] From "The significance of Cutty Sark", A discussion paper by The Cutty Sark Trust October 2003

3. Importance of the Vessel

She is the world's sole surviving extreme clipper, a type of vessel that was the highest development of the fast commercial sailing ship, with the majority of her hull fabric surviving from her original construction.

Her fine lines – a considerable part of her appeal – are defined by her frames which form part of the vessel's composite construction, a construction technique of which she is the best surviving example and of which she is of exceptional quality.

As a tea clipper, she was a participant in a significant chapter in 19th century trade and cultural life.[2]

Significantly she is the only vessel in England that was given a listing by English Heritage. This is intended to serve in some way as protection and is usually applied to buildings of significance in the UK. As English Heritage doesn't have a great deal of money, the protection is unfortunately sometimes in name only.

This also brings with it more than a few do's and don'ts with regard to how you treat the structure in question, but which can be summarized as "use as much original material as possible and don't do anything irreversible".

[2] ibid

4. Current State of the Vessel

To bring the story up to date, the typical visitor will be aware that the ship was preserved for the nation and as a memorial to merchant seamen in 1957. She resides in a purpose built dry dock, which she moved into in 1955, near the Royal Naval Hospital, now the University of Greenwich, at Greenwich on the river Thames.

The typical visitor would no doubt be familiar with this picture of the old lady:

(Cutty Sark1.jpg)

They would not, however, be so familiar with this view of the floors in the hold. These are in fact below the false deck added to aid access to the hold in 1955, so admittedly not readily visible to the visitors.

Cutty sark11.jpg

Most of the illustrations included in this paper are from the large number taken during the survey carried out in 1996, some of which needed the use of an hydraulic platform and a good head for heights. This is well illustrated by this aerial photograph of the whole ship.

Cutty Sark3.jpg

It is appropriate to cover the masts and rigging at this point. Very little of these are original, although it is believed that the lower masts may be. All the masts, spars and rigging have been renovated and renewed relatively recently and do not present a problem except to note that the fore and main masts are supported directly off the concrete central plinth below the keel.

By way of illustrating the good standards achieved aloft the following illustration is of the mizzen top rebuilt in 1996.

Cutty Sark4.jpg

Returning again to the ship, most visitors would recognize this display of figureheads in the hold:

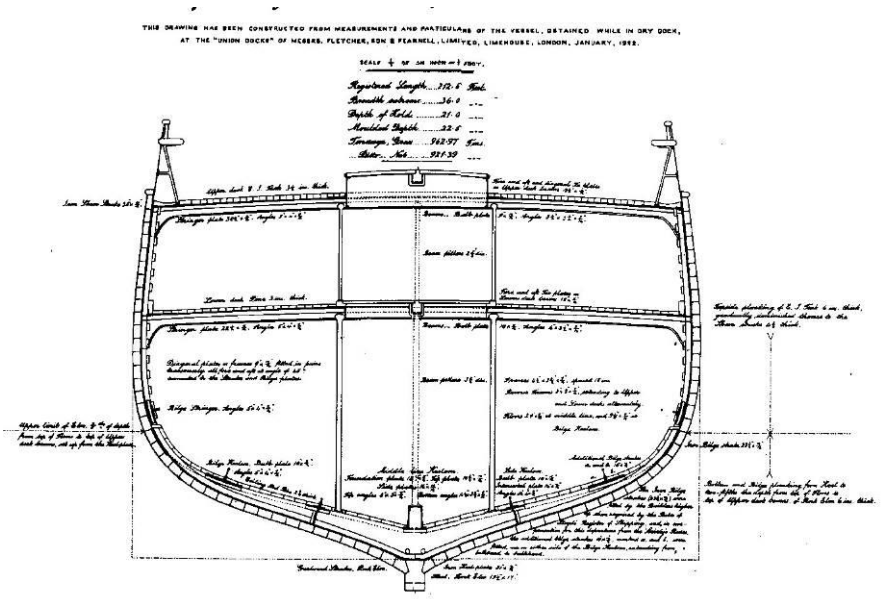
Cutty Sark6.jpg

But how many would recognize this?

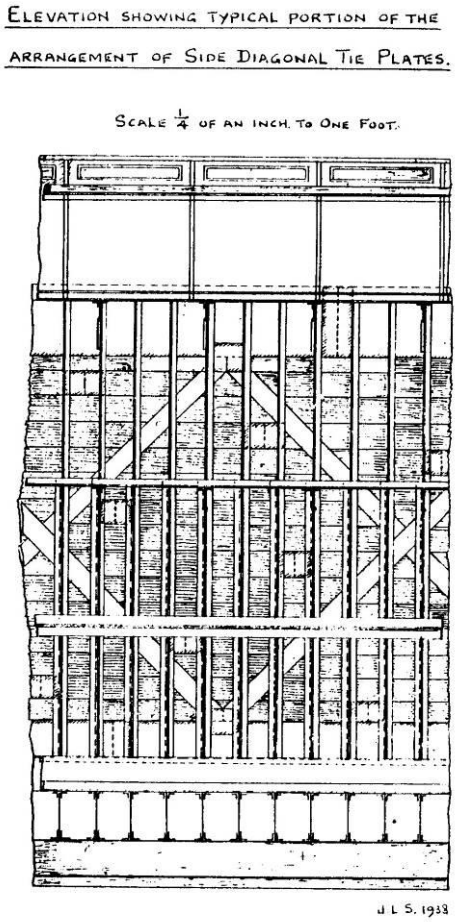
Cutty Sark7.jpg

This is one example of the corrosion damage, rust flaking off a stringer plate behind the figureheads. The whole of the wrought iron structure is suffering from corrosion and decay to a greater or lesser extent. As is only to be expected this corrosion is causing pressure between iron surfaces, which could lead joints to fail, bolts to snap and the overall structure to become unsafe.

To complete the picture a brief word about her construction would be appropriate.



Cutty Sark12.jpg



Cutty Sark13.jpg

These two figures show the wrought iron framed timber planked composite construction. Composite construction was used for some time, but wrought iron was rapidly replaced with steel as soon as production advances made it cheap enough. Thus the Cutty Sark is one of quite a small group to start with – although the UK actually has three survivors of this small group – HMS Gannet, City of Adelaide and of course Cutty Sark.

In addition to the wrought iron and timber, her lower hull is sheathed in a form of bronze, known as Muntz metal – not copper, too expensive for mere merchant ships! Whilst its main function is to deter fouling of the hull this sheathing is arranged not to let water in, nor, as it transpired, to let it out.

Cutty Sark9.jpg

The planks are held in place by Muntz metal bolts, with the wrought iron giving a perfect combination of metals for electrolytic corrosion when wet. As a result of this electrolytic action, timber adjacent to the iron also shows signs of electrolytic decay, softening to the point where a knife point can pushed in easily.

In the Cutty Sark's design, rock elm was used below the water line (simplistically speaking) and teak above. Elm does not normally survive for long out of water, another area of concern to be checked.

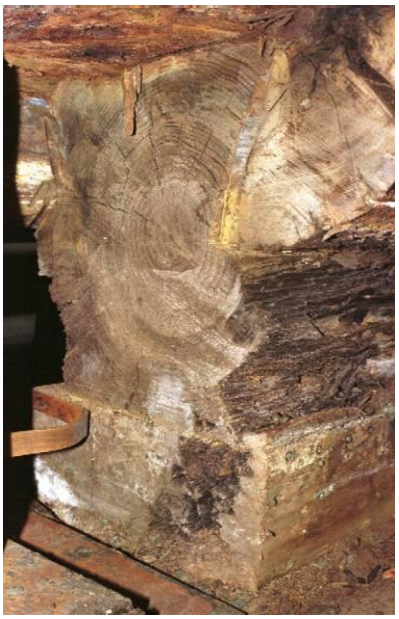
The source of all these problems can in almost all cases be directly attributed to rain leaking through the main deck. The main deck is believed to mainly consist of a triple sandwich, designed to represent the original deck when viewed from either above or below. It is believed that it even includes some roofing felt. Whilst it is difficult to find the source of a leak in a "normal" sandwich deck, it is virtually impossible with Cutty Sark's arrangement.

The result of this leak was bilges filling up with rain (and, unfortunately, wash down water) which was trapped in by the sheathing, the keel area was permanently water logged and the chlorides left in the structure from her years of service were reactivated with a vengeance.

Once Simon Waite, her then master, made the discovery in the early 90's, he removed the Muntz metal at the keel to allow the water to drain out and happily most of the keel and false keel dried out, although some replacement was necessary at the time and more is likely to be required now.

Cutty Sark20.jpg

A view of the keel on the concrete plinth showing the gaps in the sheathing.



Cutty Sark8.jpg

This is the keel and false keel after drying out.

5. The Action Plan

This sorry state of affairs was well documented by the survey report of 1997, in which the author went on record to say that the ship would become too dangerous to allow the public on board within 10 years if nothing was done to make good the ravages of time.

The first attempt at gaining financial support was, as noted above, unsuccessful. It had been felt that a period of experimentation and planning was necessary to establish final costs, but the Trust were encouraged to put a full application into the “lottery” without these figures. A mistake on everyone’s part as it transpired.

To prevent a similar occurrence, teams of specialists were assembled under the new chief executive of the Trust, Richard Doughty, tasked with going forward to a new application to the “lottery”.

6. The Team

The experts came from many walks of life, but this paper will be confined to the technical and historical side of the work.

Input came from a variety of places, the Universities of Portsmouth and Greenwich, Hampshire County Council Museums Services, from shipbuilders, suppliers and from several consultants with specialist knowledge. Each will be acknowledged somewhere in the next sections when their contribution is discussed.

7. Defining the Problem

To ensure that the costs that went into the lottery bid were as accurate as possible we needed to resolve a number of issues. The team had to determine the best method for removing the corrosion from as much of the structure as possible, to determine the cost of replacing planks (having removed them carefully in the first place!), the most appropriate timber to be used, but perhaps most importantly, how strong was the surviving structure?

8. The Deck

The problem of the “leaking roof” is relatively straightforward to solve and it will be replaced with one identical to that originally designed for the ship. Work is now progressing to find a source of suitable teak.

The wood has to be mechanically suitable, environmentally acceptable and without political taint! Technically Burmese teak would be best, but whilst this might have been acceptable a few years ago, and indeed has good, but unrecognised environmental credentials, it is no longer acceptable for such a high profile project. The search continues.

Cutty Sark21.jpg
Typical corrosion damage beneath the main deck.

Cutty Sark22.jpg
A view from the poop looking forward.

9. The Trails

Peter Lawton from Hampshire County Council Museum Services had almost perfected an electrolysis process that removes or makes inert corrosion products. It involves using a weak alkaline solution, PH 7 – 8, with an anode of titanium or stainless steel mesh held just off the hull. The metal hull acts as the cathode. A current is then put through the system, which strips off corrosion and paint alike. This was used successfully on the First World War 6 inch monitor, M33, an all-metal ship built in 1915 for service in the Dardanelles.

Cutty Sark23.jpg

Cutty Sark24.jpg

This view shows the process well underway, with visible production of hydrogen bubbles.

Cutty Sark25.jpg
This illustrates a typical set up for the anodes in M33.

Early attempts to apply it to samples of iron and wood from the Cutty Sark resulted in the wood disintegrating – a bit of a disadvantage! Happily it was at this point that Portsmouth University became involved and after some initial work, led by Dr Sheelagh Campbell and Dr Iwona Beech, determined that the addition of a biocide would solve what turns out to be a microbial problem.

Tests were carried out at the university to determine the exact level of biocide – too high and it becomes toxic waste with all the concomitant disposal problems, too low and there is a danger of losing the wood and metal to the microbes.

At this point in time it is intended to use this technique in the bilge area where the structure is badly contaminated with chlorides and likely to be very difficult to dismantle successfully.

To confirm its suitability Portsmouth University recently ran an experiment in the stern peak of the ship. Obviously it was not possible to remove the planks for this experiment and had the experiment team had to spend a considerable time stopping up leaks as the caulking was obviously not water tight any longer, a finding confirmed by the next experiment.

The results of this experiment were very encouraging; the timbers did not go soft and about 1lb of sodium chloride was extracted during a 23 day experimental period from an experiment which lasted about six weeks.

The next figure illustrates the relative cleanliness of the wrought iron structure after the experiment, with but a few discoloured patches remaining awaiting the high pressure wash down.

Cutty Sark26.jpg

One of the side effects is shown in this figure. Copper salts, iron oxide compounds and the pale sand used to try and stop up the leaks combined to produce a colourful finish to the sheathing wherever the leaks came out. It should be noted, however, that water rich in iron, which reduces pH, may adversely affect metals it comes into contact with.

Cutty Sark27.jpg

This experiment has also allowed the university team to provide a detailed quotation for the refit work.

Higher up the ship's structure, as noted, the refit will have to completely replace the deck planking and there is a choice between removing side

planking and cleaning the wrought iron mechanically, or vice versa, removing frames, cleaning them and replacing them. It is believed that may also be necessary to replace some of the more degraded planks at this stage.

To check on the cost of this process, and to gain some more information on the state of the ship's timbers, Tommi Nielsen of Gloucester was contracted to remove one plank. The elm plank selected was one that crossed a large number of wrought iron members, thus it was probably one of the weakest. Tommi and his team did a splendid job, and the ship now has a hole in the port side and the team has possession of one slightly ratty plank.

Cutty Sark28.jpg

Cutty Sark29.jpg

The team learned several things from this exercise.

The plank was basically intact and seem to have retained a degree of strength beyond expected for its species. Possibly due to being pickled by salt.

The caulking had dried to the point where it served only as a draft excluder, revealing that the planks were still separate and weren't carrying any load, a

possibility that had concerned the author ever since first seeing the corroded wrought iron.

Only something like 12% of the bolts were intact and serving their intended function. They would have to be replaced throughout, but to keep English Heritage satisfied it is proposed to melt down the old bolts and re-use the metal.

The time and effort from this work were scaled up to give a reasonable cost for work similar work throughout the whole ship.

Still concerned about the residual strength of the degraded wrought iron structure – and anxious to avoid a “house of cards” effect when work started work for real – the author suggested that the team try and apply a finite element analysis to the structure.

This has now been put in hand as part of a programme instigated by the UK Government; know as a Knowledge Transfer Partnership (KTP). This involves Prof Chris Bailey of the University of Greenwich and his team setting up the model in conjunction with the Cutty Sark staff, which will attempt to model the degraded structure, both the timber and the iron, evaluate the loads and produce a tool, which it is hoped would be sufficiently flexible that it could be applied to other degraded structures.

10. The Way Ahead

All in all, a major amount of work has been done to ensure the work needing to be done to repair the ship and keep her intact for another century was properly costed before any work is put in hand and before being included in the next application to the lottery.

It is as nothing, however, compared with the work to be done once the team get the funds. But it is to be hoped that, as a result of all this work, the Cutty Sark will still be seen over the roofs of Greenwich for some time to come.

Cutty Sark15.jpg

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Wyn Davies is a senior consultant with Frazer-Nash Consultancy Limited, having moved his historic ship business to that company just over a year ago. He has worked on a very wide range of historic ships including:

RRS Discovery, Scott's Antarctic expedition ship,
ML 1387, 1943 72 ft wooden HDML,
John H Amos, Steam Paddle Tug,
X24, Midget Submarine,
SS Robin, Steam Coaster,
HMS Stalker, 1945 Landing Ship Tank 3,
HMS Trincomalee, 1817 teak built frigate,
Dunbrody, replica Irish immigrant ship, c1850,
HMS Warrior 1862, first iron battleship,
Medway Queen, 1926 paddle steamer of Dunkirk fame,
Queen Mary, 1932 Clyde turbine steamer,
HMS Cavalier, 1944 destroyer,
PS Waverley, 1947 Clyde paddle steamer,
SS Shieldhall, operational steam ship.

He is also a member of the Heritage Lottery Fund's Directory of Expert Advisors.

Qualifications

BSc Aeronautical Engineering
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Papers Presented

"The Assessment of Safety for Vessels in Service: Practical Examples of the Application of FSA Techniques from Inland Vessels to Ocean Going Ferries", with P J Best (Frazer-Nash), I Mar E, London, 7 January 1999.

"The Preservation of Steel Warships with Particular Reference to HMS Cavalier", with J Porter, 6th Maritime Heritage Conference, Wilmington NC 25 October 2001.