Part IX Appendix B
Application of Bronze & Aluminum to Herreshoff Americas Cup Defenders

Capt. Nat's Experimentation with Bronze & Aluminum
Reviewing his Design Notebooks, we find in 1886 he is investigating the chemical and physical properties of various bronzes for ship application and by Jan. 1888 he is exploring the relative action on steel of different bronzes when immersed in sea water, including mild steel, brass riveted, to bronze plating. The contract for VIGILANT is signed in February 1893 and we find him heavily engaged in experimentation of aluminum and bronze.

- Feb 16, 18, 19 & 20, 1893- Tensile testing of plating in comparison to steel- Tobin bronze, pure aluminum, aluminum alloyed with 2% copper.
- Feb. 27, Mar. 9, 1893- Tests to failure of lap joints using hull thickness plates of steel and aluminum; series designs of rivets made from steel, aluminum and copper. Similar tests aluminum riveted lap joints.
- Oct. 25, 26, 1893- Experiments on strength of aluminum, manganese bronze, and Tobin bronze.
    - Riveted joint between aluminum and manganese (Mn) bronze with Tobin bronze rivet, test to failure.
    - Riveted joint between aluminum and Tobin bronze with same Tobin bronze rivet, test to failure.
    - Tests for transverse strength of plates Mn bronze, Tobin bronze, aluminum, nickel steel, hard rolled copper.
    - Same materials test for tensile strength.
- Feb. 7, 1895- Tests of material for HMCo 452; manganese bronze, aluminum. Tensile test, bending test & test to failure.

Source: NGH *Design Notebook Spring 1884- 1895*. Notebook 2 of 5. Access courtesy of Halsey C. Herreshoff

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Curator's Log September 2011
Nathanael Greene Herreshoff and the America's Cup:
Part Four- Bringing Bronze to the Cup

Part 3 of this series noted Capt. Nat was the first to use bronze plating in America's Cup competition. The 1893 VIGILANT, his first Cup Defender, featured a bronze plated hull and a large weighted bronze centerboard. For this application he selected Tobin Bronze, a high-strength copper-tin-zinc alloy, patented in 1876 by LT John Alfred Tobin, USN.

John Tobin was born in Barrington, RI and served as an engineer in the US Navy from 1870 to 1890. He trained in steam engineering at the Boston Navy Yard and graduated from MIT in 1876; seven years after Capt Nat completed his MIT course of study. In 1880 Tobin was detailed by the Secretary of the Navy to Great Britain to obtain information and procure plans and specifications of the most modern warships. His report, *Improvements in Naval Engineering in Great Britain*, was considered so important that Congress authorized it to be published in 1883.

VIGILANT was steel framed with bronze plated topsides (except for a mild steel sheer strake) and underwater hull ranging in thickness from 3/16 to 5/16 inches. The plating was fastened to the frames with bronze rivets. The bronze gave a hard smooth surface and below the waterline, where it was left

unpainted, resisted marine growth and corrosion. When periodically hauled, the crew was put over the side with mineral spirits and steel wool to burnish the plating.

Capt. Nat did his own material testing of the Tobin Bronze using a weight scale that he had modified to conduct pull tests of tensile specimens. (The machine is on display in the Museum's Model Workshop.) He tested for ductility (% elongation), yield strength and ultimate straight at failure. To ensure that the results represented the as-built conditions his last tensile specimens were taken from 13-foot-long finished Tobin Bronze plates ready for use in VIGILANT.

The US Navy was very interested in the potential use of bronze underwater hull plating and sent a naval constructor to Bristol to observe the work. Steel–hulled Navy ships were being docked every 6 months to remove fouling and apply new preservation. The only fix at the time was the added expense and weight of sheathing the steel with copper.

VIGILANT was not without some problems.

- The original design specified inside lead ballast in a trough of the keel. The boat proved tender in initial trials; the inside lead was removed and recast in pieces that were bolted under the keel plate.

- The hollow bronze centerboard had a tendency to jam at the wrong times. It was ballasted with lead and filled with broken coke and cement slurry. Weighing almost 8,000 lbs., a geared special-design Yale & Towne winch was required to haul the chain. The chain had to be paid out only as fast as board would take it otherwise board and chain jammed in the slot.

All in all VIGILANT was a true winner; none of the other Great Ninety-Footers had as successful a career after their Cup defenses. In commission for 11 seasons after defeating VALKYRIE for the Cup, VIGILANT, under five owners, started 89 races and won 36.

VIGILANT was broken up in New London in 1910.

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Curator's Log November 2011
Nathanael Greene Herreshoff and the America's Cup:
Part Five- Bringing Aluminum to the Cup in 1895: Capt. Nat, C. Oliver Iselin and James Maguire

Contrary to some commentary it was not the J Boats of the 1930s that introduced aluminum to Cup races, but Nat Herreshoff's 1895 DEFENDER. It is an interesting story; one that is shrouded in some mystery as to where and how the aluminum was used. This is where the research stands today.

The first all-aluminum boat was reportedly built in Switzerland in 1890 and developments in Europe continued ahead of the USA. Applications included small launches, second-class torpedo boats (carried on decks of larger vessels), gunboats and small steamers in Dutch and German African colonial service (lighter to transport over land), and at least one steamer in the Med. Experience with aluminum-copper alloy demonstrated the following:[i]

- Resistance of aluminum to seawater is possible when not in direct contact with less electro-positive metals such as brass or copper. Wherever such contact is made, the aluminum corrodes rapidly. If contact is unavoidable, either the aluminum surface should be a replaceable plate, or a layer of insulating material should separate the surfaces.
- Galvanized iron or aluminum should be used in place of brass or bronze fittings such, as rivets, in metallic connection with the aluminum hull plating.
- Aluminum-copper alloys should always be protected by paint; otherwise they will rapidly corrode by local action between the two metals.
- Unpainted aluminum is fouled by marine mollusks; but less than iron.

Capt. Nat first conducted material testing of pure aluminum and aluminum-copper alloys in February 1893 at the same time as his tests of Tobin bronze for VIGILANT.[ii]

In January 1895 Nat was hard at work completing the design for the new Cup defender and responding to urgent letters from the syndicate manager C. Oliver Iselin. Iselin was excited about aluminum thanks to a hard sell by James Maguire who, I assume, was a sales engineer for the Pittsburgh Reduction Co.[iii] Iselin urged Capt. Nat to use aluminum everywhere including bulkheads, plumbing and deck lights to achieve a "50% weight saving". He pushed Nat to talk to the president of the company, who, according to Maguire, *"Has forgotten more about aluminum than he (Maguire) knows"*.[iv]

There is no record that they talked and Capt. Nat does not mention either "the president" or Maguire in any written record. The HMCo did obtain samples of aluminum-copper alloy of differing copper content, heat-treating and metalworking from Pittsburgh Reduction. Nat personally ran tensile and bending tests on eighteen specimens, plus sheer tests of aluminum rivets; he made his material application decisions; HMCo built DEFENDER and she won the Cup.[v]

It was widely known she had steel frames, bronze underwater plating, aluminum topsides, aluminum decks and deck beams, but the knowledge of the details was lacking.

On Thursday Nov. 7, 1895, two months after the victory, James Maguire presented a paper in New York before the annual meeting of the Society of Naval Architects and Marine Engineers (SNAME)

describing the principal characteristics of aluminum and its use in ship construction in Europe and in DEFENDER. [vi] Nat, a member of SNAME, did not attend.[vii]

About the construction of DEFENDER, the paper is at the same time revealing while adding more unanswered questions.

- Maguire never mentions Nat Herreshoff or the Herreshoff Manufacturing Co by name; referring in his comments only to "the builders", "the manufacturers" and "the designers". [I take this as a demonstration that Capt. Nat did not take kindly to the pushy sales engineer who had the ear of his most important customer.]
- Pittsburgh Reduction Co.'s nickel aluminum alloy is used; the decision having been made after a great deal of experimenting on the part of "the manufacturers". Nickel alloy is 20-25% stronger than copper alloy. [Why do Capt. Nat's records include only tests of aluminum-copper alloy?]
- The plates (31 ft long x 38½" wide) and angles are the largest ones of aluminum that had been rolled up to that time.
- To assure quality a sample was tested from every plate used in the construction.
- Maguire advised "the builders" to use aluminum rivets, but "the manufacturers" did not have time to thoroughly investigate the strength of these rivets so they chose to use bronze rivets. He argued against this, and advised (1) using an iron rivet to minimize galvanic action with the aluminum plates, or (2) coat the bronze rivets with white lead. This advice however "was not listened to". [We do know that the aluminum rivets Nat tested had early failures, but we do not know why he chose bronze rivets.]
- He also advised that where the aluminum plates joined the bronze plates they place a strip of heavy flannel soaked in white lead between the plates. This was not done. [Why?]
- He revealed a number of uses of aluminum that had not been "known". Examples: blocks were wood with aluminum sheaves; the binnacle was aluminum as was nearly all the plumbing and water closets.

The most controversial discussion of the paper had to do with his description of the details as to where aluminum was used, including many areas of high stress, and his claim that another 2-3 tons of aluminum would have been used if his company had the tooling to produce structural angles of different sizes. The U S Navy had closely followed the construction of DEFENDER and, Assistant Naval Constructor Richmond P. Hobson, challenged Maguire's listings with specifics as to where steel was used in areas requiring strength. As Hobson summarized–

"This remarkable craft well illustrates the true principle to be followed in the selection of materials. Aluminum is used for lightness, steel for strength, bronze for smoothness of surface."[viii]

It would have been helpful if Capt. Nat had attended the paper and provided his comments. Since he did not, it is left to us to find the answers in his notes, design records and drawings.

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[i] The applications and experience are cited in Maguire's 1895 SNAME paper (see below) as being extracted from "*The Use of Aluminum in Marine Construction*"; Dingler's Polytechnic Journal, 1895. [Dingler's *Polytechnisches Journal* was published in Germany over a period of 111 years between 1820 and 1931.]

[ii] The 1893 tests are recorded in NGH's *Notes and Memoranda Spring 1884- April 26, 1895*. [Access courtesy Halsey C. Herreshoff] VIGILANT'S tests are discussed in Curator's Log September 2011; Nathanael Greene Herreshoff and the America's Cup: Part Four- Bringing Bronze to the Cup.

[iii] Pittsburgh Reduction Co. [now ALCOA] dates from 1888; when Charles Martin Hall, a young inventor, came to Pittsburgh in search of financial backers to commercially develop his discovery of an inexpensive method of smelting aluminum. Ref: *Aluminum's Long History in Steel City*; Joe Napsha; Pittsburgh Tribune Review. Sunday, March 5, 2006.

[iv] C. Oliver Iselin to NGH letters Jan.- Feb. 1895. NGH letter Archives. Herreshoff Marine Museum

[v] Capt. Nat's aluminum tests and design records of DEFENDER (HMCo #452) including his detail weight estimates of the vessel (Data does show changes in aluminum usage that have not been fully analyzed.) are contained in *Notes and Memoranda Spring 1884- April 26, 1895*. They cover over three months from Jan. 8 to April 26, 1895. [Access courtesy of Halsey C. Herreshoff]

[vi] *Aluminum: Its Alloys, and Their Use in Ship Construction*; James C. Maguire, Esq., Associate Member & Civil Engineer. SNAME Transactions Vol. 3 1895; pgs. 69-97.

[vii] Based upon NGH's cash account records he was in Bristol, RI on 6, 7 and 9 November.

[viii] Maguire, SNAME 1895