Condition Assessment of Historic Wood Vessels

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Abstract

This paper summarizes the field condition assessment of three historically significant wood vessels. The vessel WAPAMA, built in 1915, is the last surviving example of the wood steam-powered schooners designed for the 19th and 20th century Pacific Coast lumber trade and coastal service. The U.S. Brig NIAGARA is a wood warship of the U.S. Navy that played a pivotal role in the War of 1812 in the Battle of Lake Erie. The HIGHLANDER SEA is Grand Bank Topsail Schooner built in 1924 for use on the Great Lakes and Eastern Seaboard. A variety of state-of-the-art nondestructive testing technologies were used to complement visual techniques in evaluating physical and biological conditions of each historic wood-framed vessel. The findings provided key information about internal integrity of the primary structural members to enhance structural analyses or to support repair/replacement decisions.

Introduction

Efforts are underway to preserve landmark vessels that played nationally significant roles in the historical development of the United States. The overall goal of these efforts is to preserve, to the maximum possible extent, the historical fabric of these historic vessels. The final destination for many of these important structures is national maritime museums for use as education/historical interpretive displays. But, their journey includes a choice among a variety of pathways. The preservation path leads toward 'view-only' museum display, either with the vessel intact or with surviving portions. The restoration path leads toward major repair and replacement of deteriorated members for a fully operational vessel that can serve as a floating 'interactive' museum display. Other paths lead toward the reconstruction of historical replica vessels that are based upon available historical documentation.

Regardless of the pathway toward preservation/restoration, a comprehensive assessment of the structure in its current condition must be performed in the preliminary phase. This on-site inspection work helps to define the severity and extent of deterioration. It also provides the basis for determining the scope a f restoration work and aids in the preliminary structural analysis. The engineering challenge is to assess member integrity in historic structures without further damaging the member significantly. Therefore, the importance of nondestructive techniques for assessing the internal condition of structural members becomes apparent.

This paper summarizes the results of recent condition assessments performed on three historically significant wood vessels in the United States through a joint effort by researchers from the University of Minnesota Duluth and the USDA Forest Service, Forest Products Laboratory.

Objective

The objective of these condition assessments was to determine the physical condition of the primary struc-

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tural members of the historical wood vessels. Detailed inspection data are needed for:

1. decommissioned vessels to help define the scope of restoration work and support engineering decisions about the integrity of main structural sub-systems and
2. in-service vessels to help support decisions to either continue service, repair, or replace main structural components.

The inspections included nondestructive evaluation (NDE) techniques and traditional visual methods that collectively provide a reliable means of inspecting wood structures.

Background

Each of the three vessels described in the following case studies have their unique place in American history. A brief background for each vessel follows.

The vessel WAPAMA, built in 1915, is the last surviving example of the wood hulled, steam-powered schooners designed for the Pacific Coast lumber trade and coastal service (**Fig. 1**). Its hull design was unique for its use of sister frames and the lack of steel strapping. Douglas-fir timbers were used to build the 217-ft long, 50-ft tall, and 945 ton vessel. It primarily aided the reconstruction of San Francisco in the wake of the 1906 earthquake and fire that devastated the city. It was previously inspected in 1986 and involved visual techniques with some core sampling. At the time of the assessment in January 2006, the WAPAMA was sitting on a barge at the Richmond, California naval shipyards (**Fig. 2**).

The NIAGARA (D.S. Brig Niagara) is a squared-rigged, two-masted naval warship that helped defeat the British Navy at the pivotal Battle of Lake Erie in the War of 1812. Its original construction took place in 1813 using readily available timbers to build a 192 ft long and 120 ft tall ship vessel. It was reconstructed many times due to damage and deterioration over the years. The current vessel is a 1989 replica built with pine glued-laminated timber hull-frames (**Fig. 3**). At the time of the November 2006 assessment, the NIAGARA was moored in the harbor at the Erie Pennsylvania Maritime Museum (**Fig. 4**) for the winter.

The HIGHLANDER SEA (Highlander of the Sea) is a Grand Bank Topsail Schooner built in 1924 for use on the Great Lakes and Atlantic Seaboard. Its unique design includes a round wine glass bottom and full keel, overhanging transom design, and carvel wood planked construction. It measures 154 ft long with a 116 ft rigged height (**Fig. 5**). It is the flagship of Port Huron, Michigan where it used for public tours and educational programs. At the time of inspection in November 2006, the masts were removed for routine maintenance inside a boat warehouse (**Fig. 6**).

Methods and Equipment

Inspection methods employed in these investigations included visual, stress wave scanning, and resistance mi-

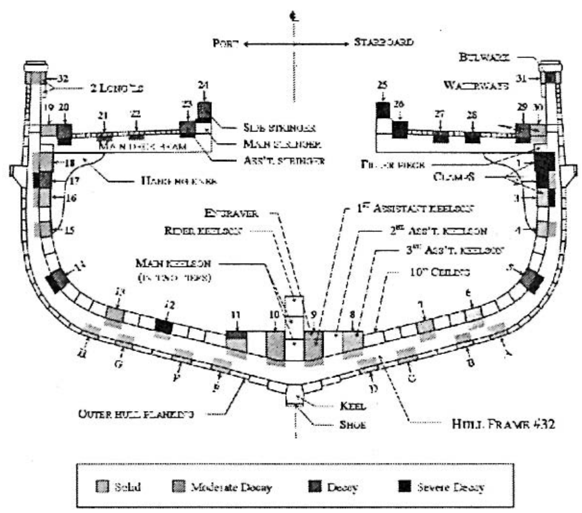

Figure 2.—*Physical condition mapping at hull frame 32 of the WAPAMA.*

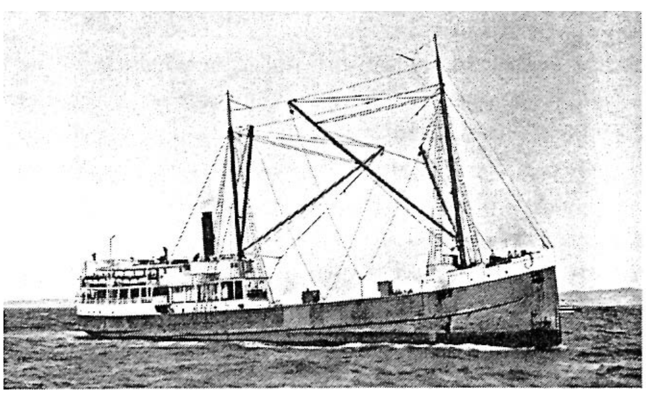

Figure 1.—*Photograph of the steam schooner WAPAMA while still in-service.*

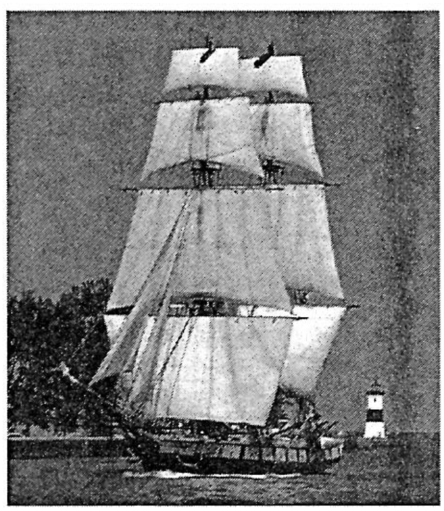

Figure 3.—*Photograph of the U.S. Brig NIAGARA while sailing in Lake Erie.*

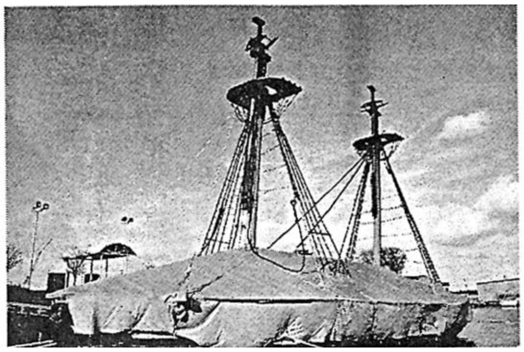

Figure 4.——*The U.S. Brig NIAGARA berthed in Erie, Pennsylvania during the November 2006 inspection.*

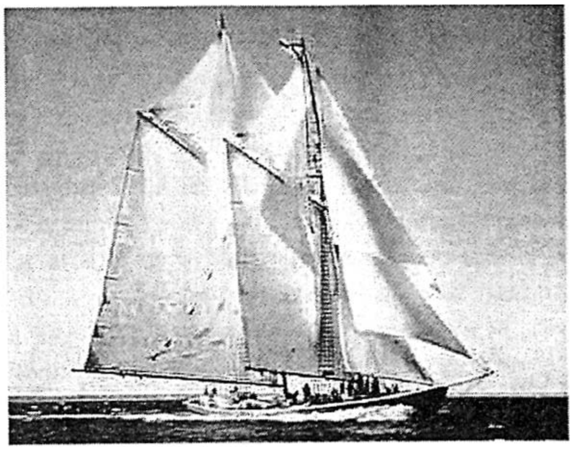

Figure 5.—*A photograph of the HIGHLANDER SEA sailing in the Great Lakes.*

cro-drilling techniques. Stress wave scanning and resistance micro-drilling are the state-of-the-art NDT techniques for assessing internal physical conditions of wood structures. When used together with visual assessment, these nondestructive techniques provide a much improved understanding of the internal integrity of structural members. A more detailed description of these nondestructive techniques and how they are applied to various wood structures is currently available in Ross et al. (2004). The main concept of the techniques is briefly described here.

Visual Inspection Techniques

The basic inspection technique is visual observation which looks for signs of deterioration, water damage, mechanical damage, or failed members. Internal deterioration can be evident by fruiting bodies, staining, or collapsed members. Visible plant growth and insect activity are also signs of advanced decay and should be further investigated. Lastly, checks and splits in treated timbers should be carefully evaluated to determine if they provide an avenue for moisture and decay into the untreated interior portion of the member.

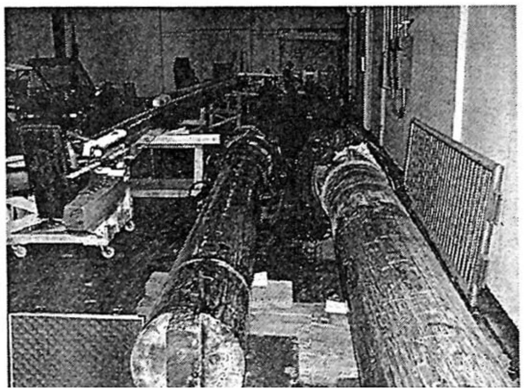

Figure 6.—*Masts of the HIGHLANDER SEA were inspected inside a boat warehouse.*

Stress Wave Scanning

The stress wave scanning (stress wave transmission) technique has been successfully used in decay detection in a variety of wood structures. The concept of detecting decay using this method is that stress wave propagation is sensitive to the presence of degradation in wood. In general terms, a stress wave travels faster through sound and high-quality wood than it does through wood that is deteriorated or of low quality. The time-of.-flight (or transmission time) of the stress wave is typically used as a predictor of the physical conditions inside the wood. By measuring the time-of-flight of a stress wave through wood member perpendicular to grain, the internal condition of the member could be determined. Further information on the principles of stress wave transmission technique and the guidelines for use and interpretation are given in FPL-GTR-119 (Forest Products Laboratory 2000).

Resistance Micro-Drilling

Resistance micro-drilling is being increasingly used in the field to characterize wood properties and detect abnormal physical conditions within structural timbers. The technique involves a quasi-destructive, mechanical drill system that measures the relative resistance (drilling torque) of the material as a rotating drill bit is driven into the wood at a constant speed. It produces a chart showing the relative resistance profile for each drill path. Because it can reveal the relative density change along the drill path, it is typically used to diagnose the internal condition of structural timbers.

A Resistograph tool typically consists of a power drill unit, a small-diameter drill bit, a paper chart recorder, and an electronic device that can be connected to the serial interface input of any standard PC. The diameter of the drill bit is typically very small, typically less than 3 mm, so that any weakening effect of the drill hole on the wood cross section is negligible. In addition, all drilled holes are typically plugged with treated wood dowels and epoxy to prevent moisture intrusion. Detailed information on the Resistograph tool is given in FPL-GTR-159 (Brashaw et al 2005) and Dunster (2000).

Case Study Results

Each of the condition assessments provided key information that aided engineering decisions to commence repair/replacement, or continue service. The specific findings and their impact on the historical vessels are described here.

WAPAMA

Our inspection focused on the key structural elements of the vessel WAPAMA which provide for the primary strength and stiffness in the transverse and longitudinal direction. Moderate and severe deterioration was observed in numerous portions of this historic ship. **Figure 2** shows a typical mapping of the physical condition at hull frame 32. The key structural elements above the water line (deck beams, frame members, and hull planking) include higher proportions of moderate to severe deterioration. The key structural elements below the water line (keel, keelsons, frame members) include only early/moderate decay with many portions remaining sound. Some of the deterioration may have taken place while the historic ship was out of the water since the roof structure was in poor shape and rainwater was pooling at the lowest portions of the hull adjacent to the keelsons. These results provided for a more precise structural analysis conducted with new information about the integrity of the wood members near the hull-frame to main deck connections. At this time, additional funds are needed before subsequent phases in the comprehensive preservation and/or restoration project can commence.

NIAGARA

Our inspection of the U.S. Brig NIAGARA focused on four pre-identified areas, which included the main mast and fore mast, keelson, waterway planks, and the forepeak. The in-service masts were deemed sound through the length. One location in the foremast was found to have moderate surface deterioration and should be monitored in the future. The keelsons are generally in good condition. Stress wave testing at selected locations indicated that keelsons were sound. But, we found that many locations in the keelsons had moisture problems (wet surface and standing water). Most locations tested on the waterway planks were found sound. The resistance profiles revealed that many parts of the waterways were likely repaired with African mahogany, as evidenced by the extremely low drill resistance. Testing results show no sign of decay on any of the cant frames and the knighthead tested. The favorable results for the masts supported the Captain's decision to extend their service lives another 1 to 2 years.

HIGHLANDER SEA

Concerns about the HIGHLANDER SEA focused on the integrity of the mast poles and whether their service could safely be extended. Our inspection was limited to the masts which were removed from the ship for routine maintenance and placed inside the boat warehouse. For the main mast, we detected several areas of moderate deterioration below the deck and above the riggings. For the fore mast, we found only one location with moderate deterioration near the top end. But, we found deep checking (up to half the diameter) along a 30-ft length at mid-height of the mast. These findings supported the owner's decision to replace both masts instead of extending service.

Summary

This paper summarizes the field condition assessment of three historically significant wood vessels: WAPAMA, NIAGARA, and HIGHLANDER SEA. Nondestructive techniques were employed during the condition assessment of various structural wood members in-service. These inspection findings supported decisions for major repairs, replacement, or continued service. These case studies also demonstrate the usefulness of nondestructive evaluation techniques in providing valuable information about the internal condition of structural members of wood ships.

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