UNITED STATES COAST GUARD

Report of the Investigation

into the

Schooner Grace Bailey (085754) Demasting with the Loss of One Life and Five Passenger Injuries on Penobscot Bay, Rockland, Maine, October 9, 2023

MISLE Activity Number: 7836612

U.S. Department of Homeland Security
United States Coast Guard

Commandant
United States Coast Guard

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16732/IIA #7836612
07 July 2025

DISMASTING OF THE SMALL PASSENGER SAILING VESSEL GRACE BAILEY (O.N. 085754) RESULTING IN THE LOSS OF ONE LIFE ON PENOBSCOT BAY NEAR ROCKLAND, MAINE ON OCTOBER 9, 2023

ACTION BY THE COMMANDANT

The record and the report of investigation completed for the subject casualty have been reviewed. The record and the report, including the findings of fact, analysis, conclusions, and recommendations are approved subject to the following comments. This marine casualty investigation is closed.

ACTION ON RECOMMENDATIONS

Recommendation 1: It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and the U.S. Forest Service (USFS) Forest Products Laboratory (FPL) to identify wooden mast material characteristics and conditions that can precede, influence, or contribute to fungal decay. In addition to those items listed in Navigation and Vessel Inspection Circular (NVIC) 02-16 Appendix (10) to Enclosure (1) and NVIC 07-95 Chapter 4, potentially relevant characteristics, and conditions, amongst many others, might include species, age, geographic harvest region, seasoning method and results, preservative treatment type and method, area of operation, moisture intrusion points and moisture content, and previous decay.

Recommendation 2: It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and the US Forest Service (USFS) Forest Products Laboratory (FPL) to determine which, if any material characteristics identified by Recommendation #1 can be reasonably monitored as part of a Preventive Maintenance Plan. Where feasible, develop inspection and documentation guidance to assist owners and inspectors with detecting and recording changes or stability of these conditions over time.

Recommendation 3: It is recommended that Commandant direct policy and/or guidance updates to require the collection and standardized recording of wooden mast material characteristics and conditions identified by Recommendation #1 within a vessel's permanent Marine Information for Safety and Law Enforcement (MISLE) record. Additionally, stability or changes of those items which can be reasonably evaluated as determined by Recommendation #2 should be recorded in a standardized format following each inspection. NVIC 02-16 Enclosure (1) III.a.iv.1 already requires marine inspectors to provide a "Detailed description of the rig and associated

gear" within MISLE or a vessel's permanent file upon completion of an annual exam. The intent of this recommendation is to provide wood mast specific guidance to supplement this record keeping requirement and to ensure that all potentially hazardous mast conditions are evaluated at each inspection.

Recommendation 4: It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and the U.S. Forest Service (USFS) Forest Products Laboratory (FPL), to evaluate non-destructive testing technologies, including internal moisture detection, and determine which, if any, are suitable for wood mast inspections. It is further recommended that Commandant direct a review of the newly formalized sail and rigging course for marine inspectors, course code 100439, and update as necessary to ensure all suitable non-destructive testing methods and their appropriate uses are adequately covered.

Recommendation 5: It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and the U.S. Forest Service Forest Products Laboratory to assess the current 10-year unstepping interval guidance for wood masts in Navigation and Vessel Inspection Circular (NVIC) 02-16 and revise if warranted.

Recommendation 6: It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and the U.S. Forest Service (USFS) Forest Products Laboratory (FPL) to evaluate industry established best practices for conducting wood mast inspections. This information should be consolidated, revised if necessary, and distributed to commercial sail vessel operators and marine inspectors by the most efficient means available.

Action: I concur with the intent of Recommendations 1 through 6. Due to the overall safety record of the domestic tall ship fleet and the decreasing prevalence of wooden masts, in particular grown masts, the Coast Guard does not intend to undertake the broad collaboration with the entities recommended at this time. However, the Coast Guard intends to address the issues raised in the recommendations during the next update to NVIC 02-16, which provides guidance for inspecting sail rigging and masts on Coast Guard inspected sailing vessels. Specifically, the next update to NVIC 02-16 will include the following:

- A review of the minimum mast inspection frequency in NVIC 02-16 and consideration of how to incorporate state-of-the-art non-destructive testing techniques and other inspection best practices identified by the investigation and from references such as the USFS FPL's Wood Condition Assessment Manual, into periodic mast inspections.

- Consideration of how to incorporate more detailed internal recordkeeping policy for wooden spars, including determining if changes to the Marine Information for Safety and Law Enforcement (MISLE) database are warranted.

- An assessment of the current 10-year unstepping interval guidance for wood masts to determine if a revised interval is warranted.

Any proposed revisions to NVIC 02-16 will be made available for public comment in the Federal Register. The Coast Guard will also review the curriculum for the Sail Rigging Course and make updates in conjunction with the update to NVIC 02-16, as warranted.

Recommendation 7: It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and U.S. Forest Service (USFS) Forest Products Laboratory (FPL) to review existing training guidance for crew members who are involved with wood mast inspections. This information should be consolidated, revised if necessary, and distributed to commercial sail vessel operators and marine inspectors by the most efficient means available.

Action: I do not concur with this recommendation. Coast Guard guidance on rigging inspections is publicly available in NVIC 02-16. Additional guidance specific to crew training is not warranted since the information in the publicly available guidance can be used by vessel owners, masters, etc., to train their crews on inspection techniques. Crew training is primarily the responsibility of the master, especially on small passenger vessels where much of the crew is not required to have a merchant mariner credential. However, the Coast Guard will consider how to improve the available guidance by incorporating state-of-the-art non-destructive testing techniques and other inspection best practices identified by the investigation, including from references such as the USFS FPL's Wood Condition Assessment Manual, into periodic mast inspections.

Recommendation 8: It is recommended that Commandant direct a review of Preventive Maintenance Plan implementation status across the Coast Guard, track industry achievement of the recommended practices, and initiate outreach to improve adherence if warranted.

Action: I partially concur with this recommendation. Preventative Maintenance Plans are an industry best-practice that the Coast Guard believes can reduce the likelihood of a rigging failure on a sailing vessel. There are currently more than 275 sailing vessels certificated to operate as small passenger vessels and approximately 110 of those vessels have wooden hulls. The Coast Guard will survey those wood vessels to determine the implementation status of Preventative Maintenance Plans and to also obtain better data on spar material (i.e., wood versus non-wood), spar construction (i.e., grown vs built), and spar age. From this effort, the Coast Guard will check for any correlations between Preventative Maintenance Plan implementation and sail-rigging deficiencies and marine casualties. If Preventive Maintenance Plans are shown to significantly enhance the safety of inspected sailing vessels, the Coast Guard will consider appropriate policy and/or regulatory changes.

Recommendation 9: It is recommended that Commandant direct a review of the Marine Information for Safety and Law Enforcement (MISLE) vessel deficiency data entry fields and

update to ensure that mast inspections, deficiencies and repairs are adequately captured and recallable for data analysis. The addition of "Mast" as a subsystem of "Sail Rigging", or the addition of "Mast" as a component of the sub-system "Spars" might achieve this. Alternatively, guidance directing marine inspectors to capture all mast specific deficiencies under a specified data field that already exists could be developed.

Action: I concur with this recommendation. The deficiency codes in the MISLE database were revised several years ago to match the codes used internationally in International Maritime Organization port state control exams. The update resulted in the removal of the "Sail Rigging" system for classifying deficiencies. Most sail rigging-related deficiencies are now documented under "02 - Structural Conditions" or "99 - Other". The Coast Guard concurs that the "Sail Rigging" system should be re-added and the subsystems and components reviewed for completeness. As such, the Coast Guard will initiate a MISLE update to re-add the "Sail Rigging" system, or something comparable, and review the subsystems and components thereunder. Further, upon completion of the MISLE updates, the Coast Guard will consider conducting a Concentrated Inspection Campaign on sailing vessels, as recommended by the First District.

Administrative Recommendation 1: It is recommended that Coast Guard District One consider appropriate recognition for GRACE BAILEY passengers and Good Samaritans who provided immediate emergency medical response for injured persons.

Action: Coast Guard District One concurred with the recommendation and subsequently worked with the Sector Northern New England Officer in Charge, Marine Inspection to initiate actions to appropriately recognize the individuals identified.

[redacted]

Wayne R. Arguin
Rear Admiral, U.S. Coast Guard
Assistant Commandant for Prevention Policy (CG-5P)

U.S. Department of Homeland Security
United States Coast Guard

Commander
First Coast Guard District

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16732
18 Dec 2024

SCHOONER GRACE BAILEY (085754) DEMASTING WITH THE LOSS OF ONE LIFE AND FIVE PASSENGER INJURIES ON PENOBSCOT BAY, ROCKLAND, MAINE, OCTOBER 9, 2023

ENDORSEMENT BY THE COMMANDER, FIRST COAST GUARD DISTRICT

The record and the report of the investigation convened for the subject casualty have been reviewed. The record and the report, including the findings of fact, analysis, conclusions, and recommendations are approved subject to the following comments. It is recommended that this marine casualty investigation be closed.

ENDORSEMENT/ACTION ON SAFETY RECOMMENDATIONS

Safety Recommendation 1. It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and the United States Forest Service (USFS) Forest Products Lab (FPL) to identify wooden mast material characteristics and conditions that can precede, influence, or contribute to fungal decay. In addition to those items listed in NVIC 02-16 Appendix (10) to Enclosure (1) and NVIC 07-95 Chapter 4, potentially relevant characteristics and conditions, amongst many other factors, might include species, age, geographic harvest region, seasoning method and results, preservative treatment type and method, area of operation, moisture intrusion points and moisture content, and previous decay.

Endorsement: Concur; my office agrees that Commandant should direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL. More specifically, we recommend a working group be developed to update or re-write NVIC 02-16 and NVIC 07-95 to identify wooden mast material characteristics and conditions that can precede, influence, or contribute to fungal decay. We encourage soliciting working group membership broadly to ship rights and wood experts.

Safety Recommendation 2. It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to determine which, if any material characteristics identified by Recommendation #1 can be reasonably monitored as part of a Preventive Maintenance Plan. Where feasible, develop inspection and documentation guidance to assist owners and inspectors with detecting and recording changes or stability of these conditions over time.

Endorsement: Concur; my office agrees in that Commandant should direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to determine which, if any material characteristics identified by Recommendation #1 can be reasonably monitored as part of a Preventive Maintenance Plan (PMP). We strongly encourage placing focus on developing guidance

for and requiring owners and operators to maintain a PMP (See Recommendation #8 Endorsement). Had mast history and maintenance data been available to U.S. Coast Guard Marine Inspectors (MIs) and third-party marine surveyors, it is reasonable to believe that they may have been able to continuously identify adverse structural changes to the mast and require appropriate repairs much earlier.

Safety Recommendation 3. It is recommended that Commandant direct policy and/or guidance updates to require the collection and standardized recording of wooden mast material characteristics and conditions within a vessel's permanent MISLE record as identified by Recommendation #1. Additionally, stability or changes of those items which can be reasonably evaluated as determined by Recommendation #2 should be recorded in a standardized format following each inspection. NVIC 02-16 Enclosure (1) III.a.iv.1 already requires marine inspectors to provide a "Detailed description of the rig and associated gear" within MISLE or a vessel's permanent file upon completion of an annual exam. The intent of this recommendation is to provide wood mast specific guidance to supplement this record keeping requirement and to ensure that all potentially hazardous mast conditions are evaluated at each inspection.

Endorsement: Concur; my office agrees that Commandant should direct policy and/or guidance updates to require the collection and standardized recording of wooden mast material characteristics and conditions within a vessel's permanent MISLE record as identified by Recommendation #1 (See Recommendation #9 Endorsement). Additionally, stability or changes of those items which can be reasonably evaluated as determined by Recommendation #2 should be recorded in a standardized format following each inspection. This investigation uncovered inconsistencies in mast material record-keeping across the Coast Guard's inspection program. In further support of recommendation #2, it is difficult for MIs to provide a detailed description of the rig and associated gear (per NVIC 02-16) if a proper PMP is not being maintained by the owner/operator.

Safety Recommendation 4. It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL, to evaluate non-destructive testing technologies, including internal moisture detection, and determine which, if any, are suitable for wood mast inspections. It is further recommended that Commandant direct a review of the newly formalized sail and rigging course (Course Code 100439) for marine inspectors and update as necessary to ensure all suitable non-destructive testing methods and their appropriate uses are adequately covered.

Endorsement: Concur; my office agrees that Commandant should direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL, to evaluate non-destructive testing technologies, including internal moisture detection, and determine which, if any, are suitable for wood mast inspections. The stress wave scanning and resistance micro-drilling techniques utilized by the investigation team were critical in identifying mast deformities that would not typically be discovered during routine U.S. Coast Guard or third-party surveyor inspections. We also concur with the recommendation that Commandant direct a review of the newly formalized sail and rigging course (Course Code 100439) for MIs. We feel it most appropriate to separate Recommendation #4 into two separate recommendations to be taken for action: One recommendation for Non-Destructive Testing (NDT) guidance, and another for review of the sail and rigging course.

Safety Recommendation 5. It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and

USFS FPL to assess the current 10-year unstepping interval guidance for wood masts in NVIC 02-16 and revise if warranted.

Endorsement: Concur; my office agrees that Commandant should direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to assess the current 10-year unstepping interval guidance for wood masts in NVIC 02-16 and revise if warranted. In line with Recommendation #1, we recommend a full review and potential re-write of NVIC 02-16.

Safety Recommendation 6. It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to evaluate industry established best practices for conducting wood mast inspections. This information should be consolidated, revised if necessary, and distributed to commercial sail vessel operators and marine inspectors by the most efficient means available.

Endorsement: Concur; my office agrees that Commandant should direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to evaluate industry established best practices for conducting wood mast inspections. It is further recommended that these best practices be implemented in the review/re-write of NVIC 02-16, NVIC 07-95, and any other mast inspection guidance and/or policy.

Safety Recommendation 7. It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to review existing training guidance for crew members who are involved with wood mast inspections. This information should be consolidated, revised if necessary, and distributed to commercial sail vessel operators and marine inspectors by the most efficient means available.

Endorsement: Concur; my office agrees that Commandant should direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to review existing training guidance for crew members who are involved with wood mast inspections. It is further recommended that these best practices be implemented in the review/re-write of NVIC 02-16, NVIC 07-95, and any other PMP guidance and/or policy.

Safety Recommendation 8. It is recommended that Commandant direct a review of Preventive Maintenance Plan (PMP) implementation status across the U.S. Coast Guard, track industry achievement of the recommended practices, and initiate outreach to improve adherence if warranted.

Endorsement: Concur with Intent; my office agrees in part that Commandant should review Preventative Maintenance Plan (PMP) implementation. My office further recommends that a regulatory change to 46 CFR Subchapters T and K to incorporate those PMP requirements. Currently the only regulation pertaining to mast maintenance is 46 CFR 176.402(c)(1) or 115.402(c)(1), which on its face is extremely vague, and only apply to "initial inspection for certification". We recommend utilizing the guidance and expertise gleaned from the above-mentioned working group(s) to advise the changes to 46 CFR

Safety Recommendation 9. It is recommended that Commandant direct a review of MISLE vessel deficiency data entry fields and update to ensure that mast inspections, deficiencies and

repairs are adequately captured and recallable for data analysis. The addition of "Mast" as a subsystem of "Sail Rigging", or the addition of "Mast" as a component of the sub-system "Spars" might achieve this. Alternatively, guidance directing marine inspectors to capture all mast specific deficiencies under a specified data field that already exists could be developed.

Endorsement: Concur; my office agrees that Commandant should direct a review of MISLE vessel deficiency data entry fields and update to ensure that mast inspections, deficiencies and repairs are adequately captured and recallable for data analysis. We agree that the addition of "Mast" as a subsystem of "Sail Rigging" would greatly benefit data analyzation and mast history records. We further recommend a Concentrated Inspection Campaign be conducted alongside the MISLE update to expeditiously evaluate mast and sail rigging data across the U.S. Coast Guard. The CIC would create a baseline condition for the national fleet to refer to during future data analysis.

ENDORSEMENT/ACTION ON ADMINISTRATIVE RECOMMENDATIONS

Administrative Recommendation 1. – Award Recommendation - It is recommended that Coast Guard District One consider appropriate recognition for GRACE BAILEY passengers and Good Samaritans who provided immediate emergency medical response for injured persons.

Endorsement: Concur; my office will coordinate with Sector Northern New England and the lead Investigating Officer on awards.

Administrative Recommendation 2. Based on the findings of this investigation, it is not recommended that any administrative or punitive action be taken against any U.S. Coast Guard personnel. It is not recommended that suspension or revocation action be taken against any credentialed mariner. Additionally, it is not recommended that criminal prosecution be taken against any person or entity.

Endorsement: Concur; my office agrees with the findings of the investigation.

[redacted]

M. E. PLATT
Rear Admiral, U.S. Coast Guard
Commander, First Coast Guard District

U.S. Department of Homeland Security
United States Coast Guard

Commander
United States Coast Guard
First District

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16732
10 October 2023

MEMORANDUM

[redacted]

From: John W. Mauger, RADM
CGD ONE (d)

To: [redacted] LCDR
COMDT (CG-INV-1)

Subj: FORMAL MARINE CASUALTY INVESTIGATION CONCERNING A DISMASTING ONBOARD THE SMALL PASSENGER SAILING VESSEL (S/V) GRACE BAILEY (O.N. 085754) ON 9 OCTOBER 2023

Ref: (a) Title 46 United States Code, Chapter 63
(b) Title 46 Code of Federal Regulations, Part 4
(c) Marine Safety Manual, Volume V; COMDTINST M16000.10A
(d) CG-545 Policy Letter 5-10

1. Pursuant to the authority contained in references (a) and (b), you are to convene a formal investigation for the marine casualty of the U.S. Flagged small passenger S/V GRACE BAILEY that occurred on October 10, 2023. In conducting your investigation, you shall follow as closely as possible the policy, guidance, and operational procedures for Coast Guard Marine Investigations Program, as found in reference (c).

2. I have assigned the following persons to assist you with your investigation. For purposes of this investigation, the below persons are all designated as investigating officers as defined under reference (b).

- [redacted] USCG, Assistant Investigating Officer
- [redacted] USCG, Recorder
- [redacted] USCG, Legal Counsel
- [redacted] USCG, Technical Expert

3. Upon completion of the investigation, you will issue a Report of Investigation (ROI) to me with the collected evidence, the established facts, conclusions, and recommendation. Conclusions and recommendations concerning commendatory actions or misconduct that would warrant further inquiry shall be referred to me by separate correspondence for consideration and action as appropriate. A weekly summary of significant events shall be transmitted to CGD ONE (dp) while the investigation is in formal session.

4. You will complete and submit your investigation report to me by June 5, 2024. If this deadline cannot be met, you shall submit a written explanation for the delay and notice of the expected completion date. You are highly encouraged to submit any interim recommendations intended to prevent similar causalities, if appropriate, at any point in your investigation.

5. CGD ONE (dpi) will furnish such funding and technical assistance as may be required by the investigation when deemed appropriate and within the requirements for the scope of the work.

#

Copy: COMDT (CG-INV)
COMDT (CG-5P-TI)
COMDT (CG-CVC)
LANTAREA
CGD ONE (dp)(dl)(de)
CG SECTOR Northern New England
Investigations NCOE

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16732
21 Nov 2024

SCHOONER GRACE BAILEY (085754) DEMASTING WITH THE LOSS OF LIFE OF ONE PASSENGER AND FIVE PASSENGER INJURIES ON PENOBSCOT BAY, ROCKLAND, MAINE, OCTOBER 9, 2023

INVESTIGATING OFFICER'S REPORT

1. Executive Summary

On Monday, October 9, 2023, at approximately 10:12 AM Eastern Standard Time, the schooner GRACE BAILEY, owned by GRACE BAILEY Navigation Company, experienced a catastrophic mainmast failure during a routine voyage, resulting in multiple passenger injuries and one fatality. The four-day excursion around Penobscot Bay began on Friday, October 6, 2023, in Rockland, ME, with 33 people on board, including 26 passengers and 7 crew members.

Despite various periods of inclement weather, including a brief period of high winds that prompted the captain to seek safe harbor, the voyage was largely uneventful. The return trip to Rockland, ME, on October 9, 2023, began without incident. However, as the morning progressed, unusual noises were heard from the mainmast. One passenger noticed the noise about an hour before the incident, and another noticed it approximately one minute before the incident, but neither recognized it as a potential warning. A third and final audible warning, recognized by multiple passengers and crew members, including the master and mate, occurred moments before the collapse. The master and mate quickly scanned the rig, identified deflection in the mainmast, and immediately called out a warning for people to get clear. Unfortunately, the mast collapsed simultaneously, leaving no time for anyone to react and move to safety.

Although the immediate response by passengers, crew, nearby vessels, and the Coast Guard facilitated a swift evacuation, the severity of one passenger's injuries required advanced medical intervention beyond the capabilities of the responders.

The scope of investigation included extensive assessment of the mainmast structure in conjunction with owners, Coast Guard inspectors, a marine surveyor, and wood assessment experts from the United States Forest Service, Forest Products Laboratory. Additionally, Coast Guard inspections procedures, as well as maintenance protocols implemented by current and previous vessel owners were assessed for the masts period of installation.

2. Preliminary Statement

2.1. This marine casualty investigation was conducted, and this report was submitted in accordance with Title 46, Code of Federal Regulations (CFR) § 4.07, and under the authority of Title 46, United States Code (USC) Chapter 63. Under 46 USC § 6308, no part of a report of marine casualty investigation, including findings of facts, opinions, recommendations, deliberations, or conclusions, shall be admissible as evidence or subject to discovery in any civil or administrative proceedings, other than an administrative proceeding initiated by the United States

2.2. The lead investigator for this investigation was Lieutenant Commander [redacted] United States Coast Guard Office of Investigations and Analysis. The investigation's legal advisor was Lieutenant Commander [redacted] United States Coast Guard, District One. Members of the investigation team included Lieutenant [redacted] United States Coast Guard, Sector Northern New England, and Lieutenant [redacted] United States Coast Guard, District One, who also served as the investigation's Recorder. The technical advisor for the investigation was Mr. [redacted] United States Coast Guard, Travelling Inspector Staff.

2.3. GRACE BAILEY Navigation Company, comprised of four individual owners and including the vessel master/operator, was designated as a Party-in-Interest (PII) to the investigation. Additionally, the mate of GRACE BAILEY was designated as a PII.

2.4. In close coordination with PIIs, the investigators collected 26 witness statements and conducted 27 interviews. At the request of the investigation team, wood assessment and mycology experts with the United States Forest Service, Forest Products Laboratory provided technical expertise in support of assessing the material condition of GRACE BAILEY*'s* masts. Additionally, PIIs provided a professional marine surveyor as a subject matter expert, whose expertise contributed to the findings of the investigation.

3. List of Figures

4. Vessel Involved in the Incident

Figure 1. Undated Photo of Schooner GRACE BAILEY (Source USCG)

Official Name:	
Identification Number:	085754, Official Number
Flag:	U. S.
Vessel Class/Type/Sub-Type	Passenger Ship/Sailing Vessel/General
Build Year:	1882
Gross Tonnage:	59 GT
Length:	72 Feet
Draft/Depth:	5.8 Feet
Main/Primary Propulsion: (Configuration/System Type, Ahead Horse Power)	Sail
Owner:	Navigation Company Rockland, ME
Operator:	[redacted] Rockland, ME

5. Deceased, Missing, and/or Injured Persons

Name	Sex	Age	Status
Emily Mecklenburg	Female	41	Deceased
[redacted]	Female	31	Injured
[redacted]	Male	54	Injured
[redacted]	Male	20	Injured
[redacted]	Male	65	Injured
[redacted]	Female	63	Injured

6. Findings of Fact

6.1. The Incident:

6.1.1. On Friday, October 6, 2023, GRACE BAILEY set out on a four-day excursion from Rockland Harbor, ME at 10:30 AM, carrying 33 people. Onboard were one master, one mate, two deckhands, one chef, one galley hand, one volunteer deckhand, and 26 passengers. Three out of four partners of the GRACE BAILEY Navigation Company, to include the master and two passengers, were aboard.

6.1.2. After leaving Rockland Harbor, the master steered an easterly course, enjoying favorable winds all day, reaching and anchoring overnight at Hell's Half Acre near Bold Island (44.153813 latitude, -66.619534 longitude) by 7:30 PM.

6.1.3. On Saturday, October 7, 2023, GRACE BAILEY left Hell's Half Acre at 8:00 AM, sailing westward under the foresail and staysail until 10:30 AM when a shallow reef mainsail was also hoisted. Morning weather was favorable with sustained winds of 16 to 19 miles per hour and gusts of 19 to 22 miles per hour. However, the master, anticipating inclement weather, decided to anchor in Kent Cove near Little Island Thoroughfare (44.147553 latitude, -66.829384 longitude) at 12:00 PM where the vessel remained until the next morning. As predicted, weather conditions worsened from 3:00 PM onwards, with winds reaching 27 miles per hour sustained and gusts up to 36 miles per hour. The high winds eased off by 1:30 AM the following day.

6.1.4. On Sunday, October 8, 2023, GRACE BAILEY raised anchor and left Kent Cove at 8:30 AM, using the yawl boat to navigate into Little Thoroughfare. In the Thoroughfare, the crew set the staysail, foresail, and a shallow reef mainsail, sailing eastward and reaching East Bay by 11:50 AM. From there, GRACE BAILEY turned north toward Oak Island Pass, arriving at 12:14 PM, where winds decreased to 16 mph sustained with 21 mph gusts. The crew shook out the mainsail reef and sailed westward towards Lasell Island, but by 2:40 PM, as they tacked around the southern end of Lasell Island, winds increased to 22 mph sustained with 28 mph gusts, prompting the crew to reset the shallow reef mainsail and take in the jib sail. GRACE BAILEY sailed around Penobscot Bay near Camden, ME throughout the afternoon. By approximately 3:30 PM, all sails were lowered, and GRACE BAILEY entered Gilkey Harbor, arriving at 4:30 PM, tying up alongside the schooner STEPHEN TABER, and remaining until the next morning.

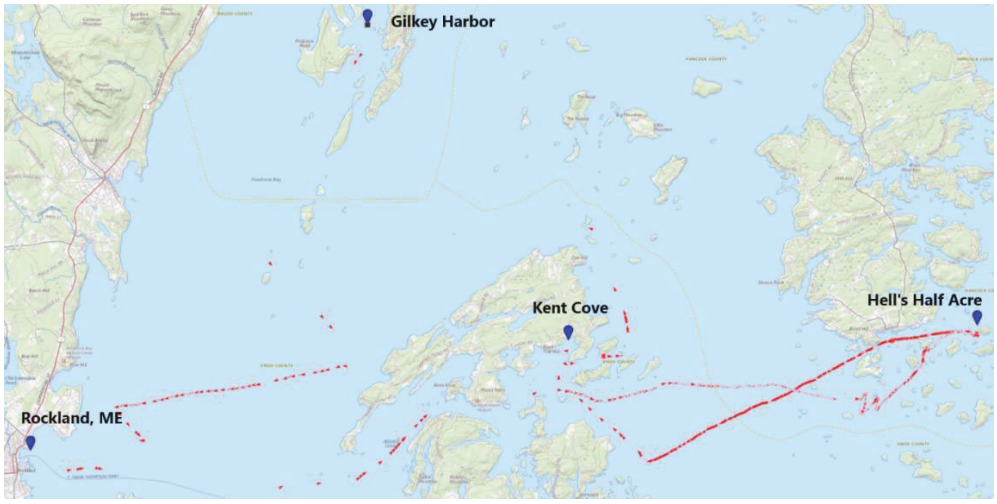


Figure 2 - Grace Baily Automatic Identification System Data - October 6-October 9, 2023. (Source: USCG)

6.1.5. On Monday, October 9, 2023, GRACE BAILEY let go of STEPHEN TABER at 8:00 AM and maneuvered out of Gilkey Harbor with the yawl boat, arriving at Penobscot Bay at approximately 8:30 AM. With favorable weather and 20 mph winds, GRACE BAILEY raised all sails and made way on a port tack, heading southeast toward Bartlett Harbor.

6.1.6. At approximately 9:16 AM, GRACE BAILEY altered course to starboard. The vessel came to 260, shifted sails to a starboard tack, and maintained course and speed for approximately six miles.

6.1.7. At approximately 9:17 AM, a single passenger standing port side abreast of the mainmast heard a noise reporting from aloft. The passenger dismissed the noise as normal for a wooden vessel and did not discuss the occurrence with any other passenger or crewmember.

6.1.8. At approximately 10:03 AM, GRACE BAILEY altered course to port. The vessel came to 140, shifted sails to a port tack, and maintained course and speed for approximately one mile.

6.1.9. At approximately 10:08 AM, the captain ordered crew to prepare to come about. Deckhands proceeded forward to work the sails. Passengers were distributed about the deck enjoying the conclusion of the excursion.

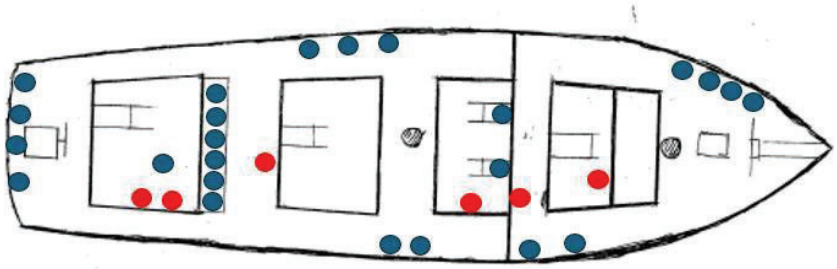


Figure 3 – GRACE BAILEY *deck arrangement with approximated positions of passengers. Red indicates injured passenger. (Source: USCG)*

6.1.10. At 10:11 AM, another passenger heard a noise aloft, described as a "rope being stretched to its limit." The passenger visually scanned the sails and rigging, determining that everything seemed normal.

Figure 4 - GRACE BAILEY from starboard after dismasting. (Maine Marine Patrol)

6.1.11. At 10:12 AM, a third noise reporting from aloft was recognized by multiple passengers and crewmembers. The captain and mate scanned the rig, finding the mainmast bending at a point approximately 75 percent up the mast. Without delay, the captain ordered everyone to get down. As he did, the mainmast collapsed, twisting, and falling to starboard.

6.1.12. [redacted] (Passenger #1), [redacted] (Passenger #2), [redacted] (Passenger #3), [redacted] (Passenger #4), and Emily Mecklenburg (Passenger #5) were struck and injured by the falling rigging. [redacted] (Passenger #6), fell down a ladderway into the vessel galley while rolling out of the path of falling rigging, resulting in injury.

Figure 5 - GRACE BAILEY full sail arrangement over broken mast. (Source: USCG)

6.1.13. (Passenger #1) was seated on the starboard aft portion of the forward cabin top, facing outboard to starboard. She was struck on the back by the lower portion of the mainmast. After being struck she remained seated/lying on the cabin top.

6.1.14. (Passenger #2) and (Passenger #3) were both seated on the starboard side of the aft cabin top directly beneath the mainmast boom. Both were struck across the shoulders and neck by the falling boom. (Passenger #2) was knocked out of the way of the boom, while (Passenger #3) was pinned in a partially seated position on the aft cabin top with the boom across his shoulders.

6.1.15. (Passenger #4) was seated on the starboard side of the forward/midship cabin top directly in front of the mainmast. He was facing outboard to starboard. He is believed to have been struck by the falling gaff, which knocked him off the cabin top and to the deck.

6.1.16. *(Passenger #5)* was seated on the forward starboard corner of the forward/midship cabin top. She is believed to have been struck across the head and back by the falling mainmast. The impact knocked her to the deck between the forward and forward/midship cabin tops.

6.1.17. (Passenger #6) was standing in the companionway in the vicinity of the galley ladder. While evading falling material, she fell down the ladder, landing in the galley.

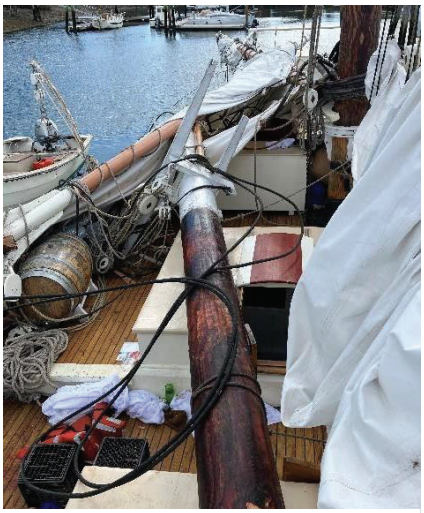


Figure 6 – Mainmast, gaff and boom as they lay after dismasting. (Source: Maine Marine Patrol)

6.1.18. At 10:13:00 AM, the captain ordered the crew to take in the headsail and foresail. He also ordered the crew to direct passengers to below deck.

6.1.19. At 10:13:57 AM, the captain initiated emergency communications with Coast Guard Station Rockland (STA Rockland) on Channel 16, to which STA Rockland answered at 10:14:04 AM.

6.1.20. At 10:14:08 AM, the captain reported the loss of mainmast and requested immediate medical assistance.

"*We're just off the Rockland break wall here. We're approximately 1.8 miles to the West. We've just lost our mainmast. We need medical assistance on board immediately."*

Figure 7 Main gaff resting atop the main boom. (Source: USCG)

This request for medical assistance was made nearly immediately after the incident and prior to the crew conducting an assessment to determine the existence, amount, or extent of any resulting injuries.

A Good Samaritan with emergency medical technician (EMT) experience who was underway in the vicinity of GRACE BAILEY heard the initial distress call and diverted course to render assistance.

Over the next 38 minutes, the captain and STA Rockland maintained constant radio contact, exchanging 115 transmissions, averaging 18 seconds between communications. During this time, the captain and STA Rockland coordinated the evacuation of injured persons. Crew, passengers, and a Good

Samaritan led on-scene emergency response, providing first aid and medical care, and securing fallen material, sails, and rigging.

6.1.21. At 10:14:27 AM, STA Rockland requested GRACE BAILEY's GPS position and the count of persons aboard.

6.1.22. At 10:14:33 AM, the captain provided GPS coordinates to STA Rockland and stated there are 28 persons onboard.

6.1.23. At 10:14:57 AM, STA Rockland requested details about the medical emergency.

6.1.24. At 10:15:04 AM, GRACE BAILEY reported being unaware of the nature of the medical emergency and indicated that attempts to assess and stabilize the situation were ongoing.

6.1.25. At 10:15:11 AM, STA Rockland asked if GRACE BAILEY was transiting into Rockland.

6.1.26. At 10:15:18 AM, GRACE BAILEY reported drifting without power, sails taken in, and yawl boat in the davits.

6.1.27. At 10:15:29 AM, STA Rockland asked if GRACE BAILEY could anchor.

6.1.28. At 10:15:33 AM, GRACE BAILEY responded negatively due to water depth.

6.1.29. At 10:15:46 AM, STA Rockland asked about personal flotation devices onboard.

6.1.30. At 10:15:56 AM, GRACE BAILEY replied that personal flotation devices were not immediately necessary.

6.1.31. At 10:16:10 AM, STA Rockland asked for a vessel description and amplifying information on medical emergencies.

6.1.32. At 10:16:20 AM, GRACE BAILEY described the vessel and reported one person under a fallen spar.

6.1.33. At 10:16:40 AM, GRACE BAILEY attempted to contact Good Samaritan (Charlie's Marine).

6.1.34. At 10:16:42 AM, the Good Samaritan responded and indicated they are enroute.

6.1.35. At 10:17:00 AM, (Passenger #7) [redacted] a recently trained EMT who was below deck in their cabin at the time of the incident was requested to come topside and assist with medical emergencies by (Passenger #8) [redacted] He ascended from below deck, finding two passengers with significant injuries, (Passenger #1 and Passenger #5). After conducting a preliminary assessment, he called for (Passenger #9) [redacted] who he understood had prior medical experience.

6.1.36. At 10:17:03 AM, STA Rockland asked if only one person was injured.

6.1.37. At 10:17:10 AM, GRACE BAILEY reported inability to confirm the number of injuries and continued efforts to stabilize the situation.

6.1.38. At 10:17:21 AM, STA Rockland informed GRACE BAILEY of a small boat enroute and again sought more information.

6.1.39. At 10:17:30 AM, (Passenger #9) joins (Passenger #7) in assessing (Passenger #5). The two passengers began preparing to initiate CPR. The chef and galley hand began assessing (Passenger #1).

6.1.40. At 10:17:44 AM, the mate notified the captain that at least two injuries occurred.

6.1.41. At 10:18:17 AM, GRACE BAILEY reported two confirmed injuries, one with a head injury to STA Rockland.

6.1.42. At 10:18:28 AM, STA Rockland asked if the injured person was conscious.

6.1.43. At 10:18:32 AM, GRACE BAILEY confirmed consciousness.

6.1.44. At 10:18:35 AM, the mate provided a first aid kit to those rendering aid and began clearing a path for assisting vessels to come alongside.

6.1.45. At 10:18:41 AM, the captain conversed with the Good Samaritan, expressing a need for EMT assistance onboard.

6.1.46. At 10:19:21 AM, STA Rockland asked about injured person's mobility and approximate age.

6.1.47. At 10:19:35 AM, GRACE BAILEY reported a 40-year-old female losing consciousness.

6.1.48. At 10:21:02 AM, the Good Samaritan contacted GRACE BAILEY to coordinate boarding.

6.1.49. Around 10:21:30 AM, the Good Samaritan was alongside GRACE BAILEY with the mate and crew assisting with lines.

6.1.50. At 10:22:00 AM, Passenger #7 and Passenger #9 began CPR on Passenger #5.

6.1.51. At 10:23:31 AM, CG-47256 attempted to contact GRACE BAILEY.

6.1.52. At 10:23:42 AM, GRACE BAILEY responded.

6.1.53. At 10:23:53 AM, CG-47256 reported five minutes to arrival.

6.1.54. At 10:24:00 AM, After initiating CPR, an onboard AED was retrieved, and a scan was conducted, determining no shock recommendation.

6.1.55. At 10:25:00 AM, the Good Samaritan boarded GRACE BAILEY, assessed

Passenger #5, and directed assisting passengers to continue CPR.

6.1.56. At 10:25:54 AM, the Good Samaritan notified STA Rockland that immediate evacuation for a CPR patient was needed.

6.1.57. At 10:26:00 AM, the Good Samaritan assessed Passenger #1, noted passenger's condition and requested evacuation by STA Rockland.

6.1.58. At 10:28:46 AM, STA Rockland attempted contact with GRACE BAILEY.

6.1.59. At 10:28:52 AM, GRACE BAILEY responded.

6.1.60. At 10:28:54 AM, STA Rockland confirmed CG-47256's proximity.

6.1.61. At 10:29:03 AM, GRACE BAILEY confirmed visual on CG-47256.

6.1.62. At 10:29:07 AM, GRACE BAILEY requested immediate evacuation for one of the injured (Passenger #5).

6.1.63. At 10:29:12 AM, STA Rockland acknowledged immediate evacuation request.

6.1.64. At 10:29:44 AM, the Good Samaritan requested CG-47256 to evacuate patient.

6.1.65. At 10:30:14 AM, GRACE BAILEY contacted CG-47256.

6.1.66. At 10:31:02 AM, GRACE BAILEY requested verification of CG-47256's ability to immediately evacuate a patient (Passenger #5).

6.1.67. At 10:31:14 AM, CG-47256 confirmed readiness for evacuation.

6.1.68. At 10:31:37 AM, GRACE BAILEY instructed CG-47256 on where to come alongside.

6.1.69. At 10:31:57 AM, STA Rockland requested EMS meeting location.

6.1.70. At 10:32:11 AM, GRACE BAILEY suggested Journey's End Marina for EMS.

6.1.71. At 10:33:00 AM, Passenger #5 was transferred to CG-47256 and departs for STA Rockland. CPR continued during transit.

6.1.72. Coast Guard requested EMS to meet CG-47256 at STA Rockland.

6.1.73. At 10:36:19 AM, GRACE BAILEY notified STA Rockland of need for further assistance, including the need for tow assistance.

6.1.74. At 10:36:59 AM, STA Rockland asked GRACE BAILEY to standby.

6.1.75. At 10:38:09 AM, the Good Samaritan requested STA Rockland to send another small boat if available.

6.1.76. At 10:38:52 AM, the Good Samaritan reported two more victims with spinal injuries needing rapid evacuation to STA Rockland.

6.1.77. At 10:39:12 AM, STA Rockland acknowledged additional victims.

6.1.78. At 10:40:28 AM, GRACE BAILEY contacted STA Rockland.

6.1.79. At 10:40:37 AM, STA Rockland responded.

6.1.80. At 10:40:41 AM, GRACE BAILEY reported precarious rigging hindering vessel maneuverability and requested patient transfer within 20 minutes.

6.1.81. At 10:41:11 AM, STA Rockland acknowledged and reported ongoing coordination for pickup of next two patients.

Figure 8 - CG-47256 and Good Samaritan vessel alongside for evacuation. (Source: Maine Marine Patrol)

6.1.82. At 10:43:09 AM, the Good Samaritan requested ETA for next Coast Guard asset.

6.1.83. At 10:43:17 AM, STA Rockland notified the Good Samaritan of current coordination efforts.

6.1.84. At 10:43:25 AM, the Good Samaritan expressed intention to evacuate patients independently.

6.1.85. At 10:45:00 AM, CG-47256 arrived at STA Rockland with EMS waiting on the dock.

6.1.86. At 10:46:25 AM, Passenger #5 was transferred to the dock and pronounced deceased by attending EMS personnel.

6.1.87. At 10:48:45 AM, CG-47256 departed STA Rockland enroute GRACE BAILEY with two EMS personnel onboard.

6.1.88. At 10:50:17 AM, STA Rockland queried GRACE BAILEY on tow urgency and reason for remaining medical evacuations.

6.1.89. At 10:50:38 AM, GRACE BAILEY reported two spinal injuries and requested tow in 30 minutes.

6.1.90. At 10:54:00 AM, CG-47256 arrived at GRACE BAILEY and transferred four injured passengers.

6.1.91. At 11:06:00 AM, CG-47256 departed GRACE BAILEY with four injured passengers. They were met at the dock by attending EMS personnel who transported injured passengers to a local hospital for evaluation and treatment.

6.1.92. At 11:08:35 AM, the Good Samaritan confirmed towing intentions with CG-

47256.

6.1.93. At 11:09:46 AM, STA Rockland confirmed with GRACE BAILEY that all injured passengers are off the vessel.

6.1.94. Between 11:19:00 AM and 12:32:00 PM, GRACE BAILEY was towed to Rockland by the Good Samaritan.

6.1.95. While being towed back to dock, Passenger #6 reported a fall injury to a partial owner of GRACE BAILEY. Passenger #6 declined medical assistance upon return to dock, preferring to arrange an examination with a private physician the following day.

6.1.96. Crew members underwent alcohol and drug testing upon return to port in accordance with 46 CFR 4.06. All test results were negative

6.2. Additional/Supporting Information:

6.2.1. **Post casualty inspections and material assessments.**

6.2.1.1. Post-casualty inspections included an initial inspection on October 19, 2023, a visual and hammer tapping inspection on October 20, 2023, a check inspection on October 21, 2023, resistance drill measurements on November 3, 2023, a comprehensive field inspection, with stress wave scanning by United States Forest Service (USFS), Forest Products Lab (FPL) on December 19, 2023, and an examination of standing and running rigging on February 7, 2024. The findings of these assessments are detailed in enclosures 4 and 5.

6.2.2. **GRACE BAILEY mast installation history and material specifications.**

6.2.2.1. In July 1990, during the final stages of an extensive drydock and rebuild project, GRACE BAILEY's previous owner identified rot of approximately three inches in depth in the lower portion of the foremast. Without prior notification to and oversight by the Coast Guard, a repair was performed at a 12:1 scarf ratio using Douglas fir and epoxy adhesive widely accepted by industry professionals.

6.2.2.2. The local Officer in Charge, Marine Inspection (OCMI) was notified of the repair by an anonymous tip, prompting Coast Guard involvement. Following an inspection of the repair, including boring samples, the OCMI allowed GRACE BAILEY to continue operating as a Small Passenger Vessel. However, the OCMI required the owner to conduct and log weekly inspections of the repair and required the previous owner to replace the mast prior to May 1991.

6.2.2.3. A Coast Guard inspection in April 1991 revealed cosmetic deterioration of the repair but no signs of rot. As a result, the

OCMI agreed to extend the mast replacement requirement and allowed the vessel to operate through October 1991.

6.2.2.4. The OCMI reminded the previous owner in November 1991 and December 1991 that the repair was considered temporary in all respects and outlined the previous owner's options to meet the issued requirement, including replacing the masts, completing repairs in the presence of a marine inspector or filing an appeal.

6.2.2.5. On January 15, 1992, the previous owner submitted a request to extend the mast replacement requirement, which the OCMI denied on January 27, 1992.

6.2.2.6. In March 1992 the previous owner ordered four new masts from a lumber supplier in the Pacific Northwest (PNW). Per the purchase agreement, the material was to be air dried straight grain Douglas fir, consist of no less than six growth rings per inch, contain knots of no more than 1.5 inches in diameter which were to be well scattered, be free from conk and rot, and contain all heartwood, no sap. The material cost was quoted at $25,000; the owner paid a $12,000 deposit. The anticipated delivery date was mid-April 1992.

ITEM #	QUANTITY	UNITS	DESCRIPTION	AMOUNT
			LATHE TURNED MASTS	
			MASTS ARE TO BE PRODUCED FROM AIR DRIED STRAIGHT GRAIN DOUGLAS FIR POLES STOCK MINIMUM 6 RINGS PER INCH, KNOTS TO BE WELL SCATTERED, MAXIMUM DIAMETER 1 1/2" MATERIAL TO BE FREE FROM CONK AND ROT ALL HEARTWOOD (NO SAP). AFTER LATHE TURNING EACH PIECE IS TO BE SANDED AND INDIVIDUALLY WRAPPED FOR SHIPMENT.	
	1	PIECE	16" TIP DIA. LATHE TURNED STRAIGHT TAPER TO 18" BUTT DIA. 70'	
	1	PIECE	16" TIP DIA. LATHE TURNED STRAIGHT TAPER TO 18" BUTT DIA. 68'	
	1	PIECE	14" TIP DIA. LATHE TURNED STRAIGHT TAPER TO 16" BUTT DIA. 62'	
	1	PIECE	14" TIP DIA. LATHE TURNED STRAIGHT TAPER TO 16" BUTT DIA. 60'	
			LUMP SUM PRICE DELIVERED	$ 25,000.00

Figure 9 -Excerpt from 1992 Purchase Order (Source: USCG)

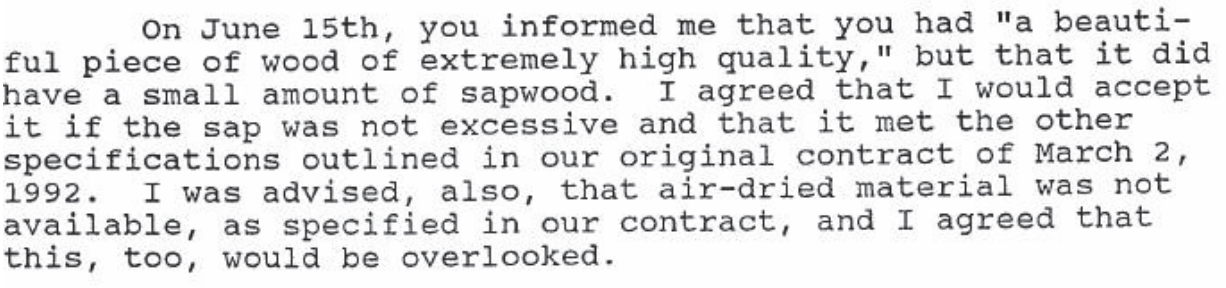
6.2.2.7. Despite ordering new masts, material delays prompted another request by the previous owner to extend the replacement requirement. The Coast Guard re-inspected the foremast in May 1992, resulting in an extension of the replacement requirement to October 1992.

6.2.2.8. In June 1992, the previous owner was notified by the supplier that mast material had been located and lathe turned, but the finished product had some sapwood remaining on the upper portion. In August 1992, the previous owner arranged for inspection of the

material by an acquaintance residing in the PNW who identified deviations from the contracted specifications.

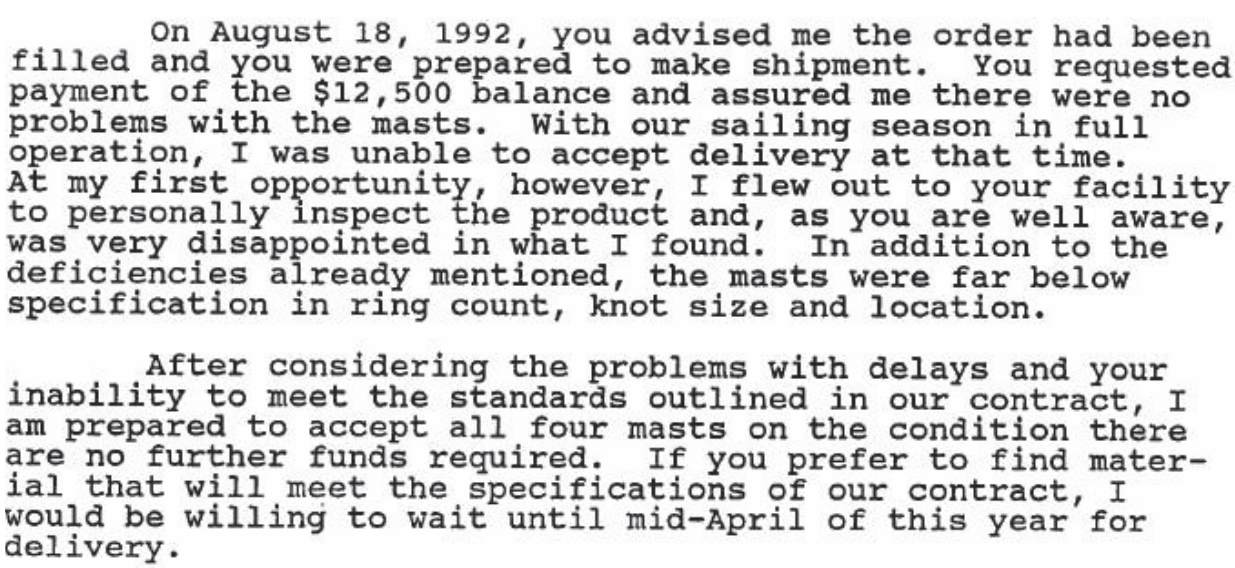
6.2.2.9. The previous owner personally inspected the material in November 1992, confirming deviations from contract specifications. Specifically, the material was not air dried, contained sapwood, was far below specified growth ring count, and did not meet the knot size and spacing specification.

6.2.2.10. The previous owner expressed concerns to the supplier in correspondence written in February 1993. Despite the material discrepancies, the previous owner expressed willingness to proceed with the purchase at a discounted cost. Alternatively, the previous owner offered willingness to wait for the supplier to locate suitable material.



On June 15th, you informed me that you had "a beautiful piece of wood of extremely high quality," but that it did have a small amount of sapwood. I agreed that I would accept it if the sap was not excessive and that it met the other specifications outlined in our original contract of March 2, 1992. I was advised, also, that air-dried material was not available, as specified in our contract, and I agreed that this, too, would be overlooked.

Figure 10 - Letter excerpt from owner to supplier - February 3, 1993. (Source: USCG)



On August 18, 1992, you advised me the order had been filled and you were prepared to make shipment. You requested payment of the $12,500 balance and assured me there were no problems with the masts. With our sailing season in full operation, I was unable to accept delivery at that time. At my first opportunity, however, I flew out to your facility to personally inspect the product and, as you are well aware, was very disappointed in what I found. In addition to the deficiencies already mentioned, the masts were far below specification in ring count, knot size and location.

After considering the problems with delays and your inability to meet the standards outlined in our contract, I am prepared to accept all four masts on the condition there are no further funds required. If you prefer to find material that will meet the specifications of our contract, I would be willing to wait until mid-April of this year for delivery.

Figure 11 - Letter excerpt from owner to supplier - February 3, 1993. (Source: USCG)

6.2.2.11. In March 1993, the previous owner notified the OCMI of complications with locating suitable mast replacement material and requested another extension, which the OCMI denied.

6.2.2.12. In April 1993, the supplier and previous owner resolved the

contract dispute. The previous owner agreed to accept four masts knowing the material did not meet the contracted specifications. In addition to the four masts, the supplier agreed to supply four peeled logs meeting dimension requirements specified by the previous owner. The supplier and previous owner also agreed to an adjusted purchase price of $18,000.

Confirming our recent conversation in exchange for your acceptance of the four masts as produced and inspected by you, we are to do the following:

1. Supply four peeled logs, free of rot, selected for straightness, in the following dimensions:

	Min. Tip	Min. Butt	Length
2 Pieces	7"	13"	40'
1 Piece	10"	12"	36'
1 Piece	24"	27"	30'

2) Change the price on the order--is to read lump sum, delivered $18,000.00.

As you have already made an advance payment of $12,500.00, there is a balance due of $5,500.00. Material will be shipped immediately upon receipt of your check.

Figure 12 – Letter excerpt from supplier to owner – April 21, 1993. (Source: USCG)

6.2.2.13. The previous owner provided payment of $5,500 for the adjusted purchase balance, facilitating acceptance of the material, which was delivered on May 22, 1993.

6.2.2.14. Although a request to extend the replacement requirement was denied in April 1993, the Coast Guard inspected the foremast on May 23, 1993, confirming the repair's integrity, and resulting in a final extension. During this inspection the Coast Guard also viewed the newly delivered masts and noted that the scantlings (mast dimensions) exceeded American Bureau of Shipping Rules for Building and Classing Wooden Vessels (1943) recommendations.

6.2.2.15. No inspection records officially document Coast Guard attendance during installation of the new masts, but an inspection from June 1994 noted the mast replacement was completed in 1993.

6.2.3. **Mainmast and Foremast Repairs in 2014.**

6.2.3.1. The mainmast and foremast were unstepped for repairs in June 2014.

6.2.3.2. The mainmast was found with an area of rot ~3 feet in length by ~9

inches in depth, 12-15 feet above the step. This section of rot was repaired by replacing the bottom 15 feet of the mast with a laminated clothespin scarf at a 12:1 ratio using West Systems epoxy.

6.2.3.3. The foremast was found with rot ~3-4 inches deep 12 feet above the step. This section of rot was excavated to good wood with new Douglas fir scarfed in at a 12:1 ratio using West Systems epoxy.

6.2.3.4. All work was completed by local shipwrights and overseen by Coast Guard inspectors.

6.2.3.5. Individuals who completed the work also assessed the upper portion of both masts at the time of repair using standard visual and hammer tapping methods. No additional rotted conditions in the upper portions of the masts were found.

6.2.3.6. Coast Guard records for the repair do not annotate what, if any, inspections were completed on the masts, before or during the unstepped period. Further, documentation for a subsequent annual inspection completed in August 2014 does not annotate any mast inspection being completed.

6.2.4. **Coast Guard Statutory and Regulatory Framework.**

6.2.4.1. GRACE BAILEY is categorized as a small passenger vessel as defined in 46 U.S.C § 2101 and is required to be inspected under 46 U.S.C § 3301, which mandates regulations governing vessel design, construction, operation, and inspections.

6.2.4.2. Statutes under 46 U.S.C § 3313 and 46 U.S.C § 3315 delineate requirements regarding vessel compliance with its certificate of inspection (COI). The statues mandate that responsible parties maintain certificated vessels, so they are always in compliance with applicable laws and regulations.

6.2.4.3. Regulations governing the inspection of small passenger vessels are promulgated in Title 46 Code of Federal Regulations (CFR) Subchapter T. Being constructed in 1882, GRACE BAILEY is subject to the Subchapter T regulations that were in place on March 10, 1996. These regulations are commonly referred to within the Coast Guard as “Old-T”. “Old-T” governs various aspects of vessel inspections, including masts, sails, and associated rigging.

6.2.4.4. Pertinent regulatory provisions relevant to masts and rigging encompassed in Subchapter T include 46 CFR 176.05-5, 46 CFR 176.05-10, 46 CFR 176.25-1, 46 CFR 176.25-5, and 46 CFR 176.30-1. However, specific criteria within the regulatory text regarding masts and rigging is limited.

6.2.4.5. 46 CFR 176.05-5 (c) requires that the initial inspection for certification be such to ensure that the materials, workmanship, and condition of all parts of the vessel and its machinery and equipment are in all respects satisfactory for the service intended.

6.2.4.6. 46 CFR 176.05-10 (a) requires that an inspection for renewal of a certificate of inspection include an inspection of the structure, machinery, and equipment to ensure the vessel is in satisfactory condition and fit for the service for which it is intended.

6.2.4.7. 46 CFR 176.25-1 (a) requires that vessels be inspected for compliance with the standards of Subchapter T. For items not covered by Subchapter T, inspection shall be in accordance with standards acceptable to the OCMI, as good marine practice.

6.2.4.8. 46 CFR 176.25-5 (a) (3) requires the condition of the masts, spars, standing rigging, running rigging, blocks, fittings, and sails to be checked at each initial and subsequent inspection.

6.2.4.9. 46 CFR 176.30-1 authorizes marine inspectors to make such tests or inspections as are reasonable and practicable to be assured of the seaworthiness of the vessel.

6.2.4.10. Regulations do not prescribe inspection procedures or acceptance standards for masts and rigging. Regulatory text applicable to masts and rigging largely relies on terms like "satisfactory for intended service" and "good marine practice”.

6.2.4.11. Third-party standards, including Lloyd's Rules and Regulations for the Classification of Yachts and Small Craft, Part 2, Hull Construction, 1983 (Lloyd’s 1983) are referenced as guidance in the regulations. Marine inspectors can apply guidance from these standards so long as they do not conflict with regulatory requirements.

6.2.4.12. Lloyd’s 1983 provides guidelines on timber selection, moisture content, preservative treatment, and overall material suitability.

6.2.4.13. While Lloyd's 1983 highlights the importance of owner expertise in evaluating masts, rigging, and sail arrangements, it requires marine inspectors to ensure these components are constructed from suitable materials, properly fitted, and in optimal working condition.

6.2.5. **Coast Guard Safety Policy Framework.**

6.2.5.1. The Coast Guard Safety and Environmental Health Manual (SEHM), Chapter 24, serves as the guiding document for the Coast Guard fall protection program (FPP). It references Occupational Safety and Health Administration (OSHA) regulations in Title 29

CFR 1910, 1915, and 1926, and the Coast Guard's Fall Protection Program Tactics, Techniques, and Procedures Manual 4-11.15.

6.2.5.2. The SEHM extends to all Coast Guard operational and support activities, encompassing afloat, ashore, aviation, and industrial operations.

6.2.5.3. Coast Guard units with personnel working at heights, exposed to fall hazards, and utilizing fall protection must establish, implement, and oversee a FPP compliant with OSHA standards.

6.2.5.4. The SEHM requires personnel to be provided with fall protection when exposed to fall hazards, including elevated walking, or working surfaces with unprotected sides, edges of roofs, or floor openings from which a fall of four or more feet is possible.

6.2.5.5. For shipyard settings, the SEHM height threshold for fall protection is raised to five feet. This applies to individuals engaged in shipbuilding, repair activities, and inspections within shipyards or on vessels.

6.2.5.6. Sector Commanders are mandated by the SEHM to develop and execute a FPP compliant with OSHA regulations. This entails designating a competent person to oversee the FPP, establishing safe work practices, implementing fall prevention and control measures, providing adequate fall hazard training, ensuring proper inspection and maintenance of personal protective equipment (PPE), establishing aloft rescue procedures, and supporting subordinate units in program development and training.

6.2.5.7. Marine Safety Manual (MSM) Volume I, Chapter 10 outlines Coast Guard policy concerning the establishment of Safe Work Practices (SWP) for Marine Safety Activities. SWPs serve as a primary administrative control measure for marine safety operations, which often occur beyond the direct control of the Commanding Officer.

6.2.5.8. Minimum hazards necessitating the development of SWPs are dictated by MSM Volume I, Chapter 10. Working at heights is not included as an identified hazard.

6.2.5.9. Although the SEHM applies broadly across all Coast Guard Missions, the adoption of fall protection standards in the marine safety program is limited.

6.2.5.10. The absence of FPPs and supporting SWPs effectively prohibits marine inspectors from conducting aloft inspections.

6.2.6. **Coast Guard Marine Inspection Policy Framework.**

6.2.6.1. MSM Volume II, Chapter 3.C.f discusses the importance of detailed inspection records to aid subsequent inspectors. It emphasizes the necessity of including specific information regarding examined components within a random sampling to facilitate future inspection efficiency and effectiveness.

6.2.6.2. MSM Volume II, Chapter 7, delineates guidelines for the proficiency of commercial vessel compliance personnel. It defines a marine inspector as an officer or civilian tasked with executing the field duties of the Commercial Vessel Safety Program. Such inspectors must possess and apply comprehensive knowledge of federal statutes, regulations, Coast Guard policy, and industrial standards to inspect vessel construction, alterations, repairs, equipment, and operating procedures across various vessel types.

6.2.6.3. MSM Volume II outlines the attributes of an optimal marine inspector, emphasizing technical expertise in the maritime transportation system, sound judgment in regulatory application, considerations of commerce, public safety, and environmental risk, commitment to the Coast Guard's marine safety mission, dedication to professional development, and recognition as a leader in the marine safety community.

6.2.6.4. MSM Volume II defines competency as a collection of tasks accompanied by requisite skills, knowledge, and abilities needed to achieve predetermined standards. Certification, on the other hand, denotes endorsement by the Sector Commander or designee, indicating that specified knowledge and performance standards have been met or maintained for a particular competency.

6.2.6.5. MSM Volume II describes currency as the maintenance and proficiency of knowledge associated with a particular certification, typically demonstrated by conducting inspections within specific timeframes.

6.2.6.6. Mandatory formal training relevant to marine inspectors currently assigned to Marine Safety Detachment Belfast includes attendance at the Marine Inspector Course (Course Code 501869), with additional training applicable to specific vessel platforms, such as Fiberglass Reinforced Plastic and Wooden Boats (Course Code 340210). The Marine Inspector Course has since been replaced by the Marine Inspection Performance Support Architecture. A sail and rigging course and wood vessel inspection course have been formally incorporated into the marine inspector training program.

6.2.6.7. MSM Volume II emphasizes subsequent inspections' importance for certifications, ensuring vessels and their equipment are maintained safely and compliant with relevant laws and

regulations. Inspectors must utilize all available evidence to evaluate vessel conditions, reaching independent conclusions based on inspections and expert opinions.

6.2.6.8. Marine inspectors are obligated to ensure vessels possess suitable structures, are fully in compliance with laws and regulations, and safe for proposed services.

6.2.6.9. The marine inspector's obligations include verifying vessel compliance with statutes, regulations, and Certificate of Inspection terms, conducting inspections consistent with certification requirements, and consulting with the Officer in Charge, Marine Inspection (OCMI) when uncertainty arises.

6.2.6.10. Utilizing various sources of information, including inspection findings, records, expert opinions, and classification society standards, marine inspectors assess vessel conditions and make informed decisions to ensure compliance and safety. Accepted classification society standards referenced include those of the American Bureau of Shipping (ABS) and Lloyd's Register of Shipping.

6.2.7. **Coast Guard Procedural Guidance – Navigation and Vessel Inspection Circular (NVIC) 02-16.**

6.2.7.1. On April 13, 2016, the United States Coast Guard issued NVIC 02-16, titled "Inspection Guidance for Sail Rigging and Masts on Inspected Sailing Vessels."

6.2.7.2. The primary objective of NVIC 02-16 was to offer comprehensive guidance to various stakeholders, including vessel owners, riggers, marine surveyors, and Coast Guard marine inspectors, regarding the inspection of sail rigging, masts, and associated components on inspected sailing vessels. The guidance promotes preventive maintenance as a fundamental marine practice.

6.2.7.3. NVIC 02-16 urged OCMIs, vessel owners, operators, or their representatives to utilize the procedures and guidelines outlined in the circular.

6.2.7.4. NVIC 02-16 suggested that Coast Guard marine inspectors should refer to the provided guidance when conducting inspections on sailing vessels.

6.2.7.5. NVIC 02-16 emphasized the importance of adhering to recommended maintenance and inspection frequencies to avoid unnecessary expenses for vessel owners/operators.

6.2.7.6. NVIC 02-16 highlighted the significance of proactive and thorough periodic examinations by vessel owners and operators to monitor

wear, corrosion, service life, and potential rigging failures.

6.2.7.7. While regular rigging inspections were mandated by existing regulations, NVIC 02-16 pointed out the absence of specific time intervals for unstepping masts.

6.2.7.8. NVIC 02-16 identified the need for documented preventive maintenance plans (PMPs) to aid sailing vessel owners/operators in effectively assessing the condition of their sail rigging systems.

6.2.7.9. The NVIC recommended the inclusion of various elements in a PMP, such as a general vessel description, examination and maintenance schedules, inventory of rigging components, and documentation of rigging examinations and maintenance.

6.2.7.10. Coast Guard inspections, per NVIC 02-16, could be facilitated by the presence of a PMP onboard a vessel, enabling marine inspectors to review its implementation and evaluate the credentials and experience of individuals involved in PMP activities.

6.2.7.11. In the absence of a PMP, Coast Guard inspectors may require a third-party rigging survey to verify the condition of a vessel's sail rigging and components.

6.2.7.12. NVIC 02-16 reiterates that Coast Guard marine inspectors are not expected to conduct surveys aloft due to the lack of Personal Protective Equipment (PPE) specific to such activities. Instead, visual aids from the deck level are recommended. When visual inspection reveals questionable items, the marine inspector may require the owner to validate material condition through any available means, including a third-party survey or inspection by a qualified crew member.

6.2.7.13. NVIC 02-16 provides guidance on rigging inspection practices, including the use of visual examinations, non-destructive testing (NDT), and unstepping masts at intervals acceptable to the OCMI to ensure thorough inspections.

6.2.7.14. While the NVIC outlines wood spar grade standards and recommended intervals for mast removal and comprehensive inspections, specific guidance on how to conduct those inspections is not included.

6.2.8. **Coast Guard Procedural Guidance – NVIC 07-95.**

6.2.8.1. NVIC 7-95 provides guidance for marine inspectors regarding wood defects and preservatives used in marine applications.

6.2.8.2. NVIC 7-95 explains that wood defects such as knots, checks,

excessive warp, splits, and pitch pockets should be carefully evaluated and rejected for use in hull structure applications.

6.2.8.3. While NVIC 7-95 does not require the use of wood preservatives, it explains that their application under severe service conditions can significantly reduce decay and borer attacks, thereby decreasing repair and replacement costs and enhancing vessel safety and longevity.

6.2.8.4. NVIC 7-95 dictates that wood preservatives for marine use must not pose a toxic hazard to the crew, should be odor-free, and must effectively combat decay fungi and marine borers in moist conditions.

6.2.8.5. NVIC 7-95 explains that detection of serious wood deterioration within a hull is challenging as outward signs may be minimal. Sounding with a hammer and probing with care can help identify decayed wood, which often requires complete renewal.

6.2.8.6. NVIC 7-95 explains that moisture content ranging from 20% to 80% is conducive to fungus growth in wood, leading to decay. Dry or waterlogged wood does not rot.

6.2.8.7. NVIC 7-95 explains that careful probing and boring are essential to avoid creating potential entry points for wood borers. Non-destructive testing should precede any probing, and routine probing should be avoided.

6.2.8.8. NVIC 7-95 explains that decay is commonly found in mast fastening locations, natural checks, compression cracks, and areas covered with metal or leather chafing gear.

6.2.8.9. NVIC 7-95 explains that when deficiencies are identified, marine inspectors must evaluate their extent and impact on seaworthiness. Factors such as the progressive nature of the defect, timing of the next inspection, and the necessity of repairs to restore seaworthiness must be considered.

6.2.9. **Sector Northern New England (SNNE) Local Instruction (MPS-WI-NNE-13(01).**

6.2.9.1. The SNNE Work Instruction serves to document local policy concerning the structural examination of wood-hulled small passenger vessels. It aims to standardize examination practices and offers inspection guidance.

6.2.9.2. Applicable to SNNE Prevention Department personnel, including MSD Portsmouth and MSD Belfast, the instruction references various sources, including NVICs 7-95 and 02-16, 46 CFR Parts 176 and additional publications related to boat building, repair, and

maintenance.

6.2.9.3. The document is not a substitute for legal requirements, nor does it impose binding obligations on non-Coast Guard entities. It emphasizes the use of marine inspectors' expertise and available resources, cautioning against considering it a comprehensive checklist.

6.2.9.4. The SNNE Work Instruction dictates that structural examinations involve visual assessment of the external hull envelope, internal compartments, and watertight bulkheads, accompanied by hammer testing or probing of suspect planks or members.

6.2.9.5. The SNNE Work Instruction explains that credit hull exams during dry dockings necessitate a thorough visual examination of the entire hull envelope, including inspection of keel alignment, along with internal compartment inspection, ensuring structural integrity and adhering to confined space entry safety precautions.

6.2.9.6. The SNNE Work Instruction explains that hammer testing may not be reliable in freezing conditions, warranting caution during assessments. Dry-dock examinations for wooden vessels are typically avoided during winter months, except under unusually warm conditions.

6.2.9.7. The SNNE Work Instruction explains that mast and rigging inspections follow guidance outlined in NVIC 02-16. Annual inspections include examining mast steps, chain plates, and deck areas, while mast disassembly and examination occur at 10-year intervals. Marine inspectors do not ascend aloft for inspections.

6.2.10. **Marine Safety Detachment Belfast Staffing and Training.**

6.2.10.1. Marine Safety Detachment (MSD) Belfast is a sub-unit of SNNE and is primarily responsible for inspections of GRACE BAILEY.

6.2.10.2. The MSD Belfast inspection team is comprised of a Civilian Marine Inspector and a Chief Warrant Officer Marine Inspector.

6.2.10.3. The Civilian Marine Inspector has been assigned to MSD Belfast since 2014. Prior experience dating to June 2002 includes tours at Marine Safety Office Philadelphia/Sector Delaware Bay, Sector Long Island Sound, and additional tours at MSD Belfast. Inspector’s training record includes the Coast Guard’s Marine Safety Initial Indoctrination, Fiberglass Reinforced Plastic and Wooden, and T- Boat Structural Plan Review courses. The inspector holds ten marine inspector competencies, including T-Boat inspection which was acquired in 2003.

6.2.10.4. The Chief Warrant Officer Marine Inspector has been assigned to

MSD Belfast since 2020. Prior experience dating to March 2009 includes tours at Sector New York, Sector Southeast New England, and additional tours at MSD Belfast. Inspector's training record includes Inspection Guidance for Sail Rigging and Masts on Inspected Sailing Vessels, delivered by the Coast Guard's Office of Commercial Vessel Compliance (CG-CVC-1) in 2019. Inspector holds nine marine inspector competencies, including T-Boat inspection which was acquired in 2011.

6.2.10.5. Both marine inspectors met the training, competency, certification, and recency requirements annotated in MSM Volume II.

6.2.10.6. In post casualty interviews both inspectors demonstrated a comprehensive understanding of regulatory requirements. Additionally, they both noted that applicable regulations lack specific mast inspection acceptance criteria.

6.2.10.7. Both individuals exhibited proficiency in Coast Guard mast inspection procedures applied during annual and 10-year unstepped inspections. Their annual inspection procedure involves visually examining accessible mast sections from on deck and below deck levels. They confirmed the prohibition of aloft inspections, stating they rely on binoculars and photographic evidence for visual assessments.

6.2.10.8. During annual inspections, they focus on visual indicators such as discoloration, signs of wood compression or damage, and areas of rust near mast penetrations that can indicate potential moisture intrusion. Their inspection procedures aligned with relevant guidance outlined in NVIC 7-95, NVIC 2-16, and SNNE Wood Boat Guide MPS-WI-NNE-ISNP-13(01).

6.2.10.9. During 10-year unstepped inspections, they rely on visual examinations to determine if further examination using other traditional methods like hammer tapping and light probing is warranted.

6.2.10.10. Neither inspector recalled personally identifying areas of rot on masts during any inspection they had participated in. Instead, they indicated that mast repairs they had been involved with typically originate from findings reported to the Coast Guard by vessel owners or third-party surveyors.

6.2.10.11. Historically, their primary role in mast inspections has involved evaluating repair plans submitted by owners and operators, ensuring those plans comply with relevant standards, and overseeing repair completion.

6.2.10.12. Despite meeting all training and knowledge requirements outlined in Coast Guard policies, they primarily rely on owners, operators,

and third-party surveyors to identify and report rotted conditions in masts.

6.2.11. **GRACE BAILEY's Coast Guard Inspection History.**

6.2.11.1. MSD Belfast has conducted 18 inspections on GRACE BAILEY since the masts were last unstepped in 2014, including two Inspections for Certification, eight Annual Inspections, six Dry Dock Inspections, and one Damage Survey/Examination of repairs.

6.2.11.2. The completion of mast and rigging inspections in conjunction with the above inspections was not consistently documented in inspection reports maintained by the Coast Guard. Of the 18 inspection reports, eight include data entries reflecting completion of a mast inspection.

6.2.11.3. Mast examinations were documented in 0/2 Inspections for Certification, 4/8 Annual Inspections, 3/6 Dry Dock Inspections, and 1/1 Damage surveys/Examinations of Repairs.

6.2.12. **Coast Guard Mast Inspection Records.**

6.2.12.1. The Coast Guard documents inspections in the Marine Information for Safety and Law Enforcement (MISLE) database. This database is the standard repository from which results of inspections are entered.

6.2.12.2. MISLE does not include mast specific data entry fields. Instead, marine inspectors document mast deficiencies under various "System" categories including "Sail Rigging" and "Structural Conditions". The "Sail Rigging" category includes several "Sub-Systems" and "Components", none of which are specific to masts.

6.2.12.3. The Coast Guard uses a separate application/program, Coast Guard Business Intelligence (CGBI), to cull MISLE inspection data for trend analysis.

6.2.12.4. While CGBI can compile marine inspection metrics encompassing nearly every MISLE data entry field, MISLE data entry fields specific to masts do not exist.

6.2.12.5. Given the technology limitations, the Coast Guard does not have the ability to easily compile and assess mast inspection or deficiency data and trends, including unstepping intervals, deficiencies found, repairs completed, mast/spar age and installation date, source of supplier, geographic harvest location, whether material is grown or laminated, growth ring count, seasoning method, preservative treatment type and application method, seasoning method, or the presence of shakes, cracks,

checks, knots, or spiral grain.

6.2.12.6. While marine operator development and implementation of a PMP is not compulsory, MISLE does not include data entry fields to reflect whether operators have a PMP in place, and whether a PMP includes specific mast inspection and maintenance requirements.

6.2.13. **Third party professional marine surveys and Coast Guard marine inspections ahead of vessel purchase**.

6.2.13.1. On May 5, 2022, the previous owner contracted an Insurance Survey of the vessel through a local marine surveyor. During this survey, the surveyor identified minor rot in the foremast boom saddle. No other conditions related to spars, sails, or rigging was found. The surveyor recommended the owner repair the rot in the foremast boom saddle as needed. Additionally, surveyor recommended the owner perform inspections as required by NVIC 02-16.

Figure 13 - Rot in foremast boom saddle found during survey, May 5, 2022, (Source: Maine Design report of survey)

6.2.13.2. MSD Belfast conducted an annual inspection on June 6, 2022, with no mast deficiencies identified.

6.2.13.3. On July 9, 2022, MSD Belfast completed a Damage Survey following a marine casualty in which GRACE BAILEY collided with schooner AMERICAN EAGLE. The collision resulted in GRACE BAILEY's jibboom spar breaking, requiring replacement. During this inspection, the inspector examined the standing and running rig from deck level, noting that only the jibboom spar was affected.

6.2.13.4. On July 27, 2022, MSD Belfast completed an Examination of Repairs, noting a new jibboom spar had been installed and all standing rigging remains unaffected.

6.2.13.5. On November 23, 2022, GRACE BAILEY Navigation Company contracted a pre-purchase survey through the same local marine surveyor who completed the Insurance Survey on May 5, 2022. During this survey, the surveyor identified a 10 inch by 1 inch area of rot on the starboard side of the foremast under the boom saddle. The surveyor recommended that rot in the foremast be investigated further and repaired, noting the mast would need to be unstepped to facilitate repairs.

Figure 14 - Foremast rot identified during survey, November 23, 2022. (Source: Maine Design report of survey)

6.2.13.6. The insurance survey in May 2022 and the pre-purchase Survey in November 2022 both included an examination of the masts, spars, and rigging. The surveyor's examination of masts, spars, and rigging is limited to a visual inspection from deck level unless the purchaser specifically requests an aloft inspection. The surveyor was not requested to conduct an aloft inspection during either survey.

6.2.13.7. GRACE BAILEY Navigation Company purchased GRACE BAILEY on December 8, 2022.

6.2.14. **Foremast Repair 2023.**

6.2.14.1. On March 21, 2023, the operator of GRACE BAILEY notified MSD Belfast of the rot that was previously identified during the pre- purchase survey conducted on November 22, 2023. MSD Belfast was advised that exploratory drilling had been completed, indicating repairs will not extend 50% into the mast. Further, MSD Belfast was notified that a scarf repair proposal would be submitted later.

6.2.14.2. On May 9, 2023, MSD Belfast received a scarf repair proposal from the operator. The proposal called for a 104-inch length by 3 ½ inch depth scarf repair of Douglas fir and West Systems epoxy. The marine inspector authorized the operator to proceed with repairs.

6.2.14.3. The repair was completed with the mast stepped in place, using threaded rod clamps every 12 inches to ensure a tight fit.

6.2.14.4. On May 25, 2023, a marine inspector from MSD Belfast attended

GRACE BAILEY to examine completed repairs, finding the work satisfactory.

6.2.14.5. On May 31, 2023, MSD Belfast attended GRACE BAILEY to conduct an annual inspection, noting that masts and standing rigging were viewed with no deficiencies noted.

6.2.15. **Previous owner maintenance and inspections 1994-2022.**

6.2.15.1. The previous owner did not have a formal maintenance or inspection program for the masts.

6.2.15.2. The previous owner preferred to leave mast checks open to prevent water entrapment and promote drainage. However, post-casualty evaluation revealed most checks were filled with wax/oil-based material.

6.2.15.3. Crew members were expected to visually inspect the masts in conjunction with bi-annual slushing. However, crew members were not trained in mast or wood inspection procedures or methods and were not provided with mast inspection guidance or expectations. Mast inspections conducted by the crew were limited to visual observations. Traditional wood assessment tools, including sounding hammers and probes were not utilized.

6.2.15.4. Prior owner primarily relied on mast inspections conducted annually and at 10-year intervals by the Coast Guard.

6.2.15.5. Documentation for inspections conducted by crewmembers was not maintained.

6.2.15.6. Mast maintenance was limited to bi-annual slushing, completed by the crew.

6.2.16. **Owner/Operator maintenance and inspections 2022-2023.**

6.2.16.1. Upon purchase, the operator installed foremast ratlines from the starboard bulwark to the trees and mainmast ratlines from the port bulwark to the trees. Ratlines are ladders comprised of rope/lines that are used for aloft access. Ratlines were not previously installed.

6.2.16.2. The operator delegated responsibility for mast and rigging inspections to the mate. The mate had prior experience on sailing vessels and had received on-the-job training for sailing operations during previous employment. The mate’s training was primarily operational but also included some on-the-job training for sail and rigging inspections. The mate had not received mast or wood inspection training.

6.2.16.3. The mate's employment on GRACE BAILEY began in March 2023. The mate's duties included conducting monthly inspections of the sail and rigging system aloft and daily rig inspections from deck level. Inspections purportedly included inspecting the masts and were required to be documented in the vessel rig log.

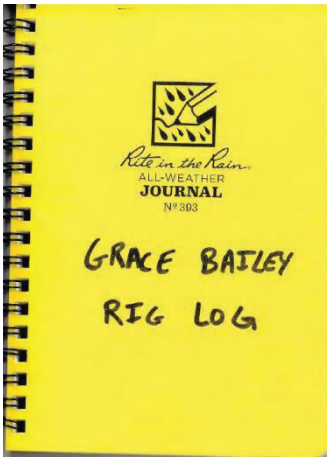


Figure 15 GRACE BAILEY Rig Log Cover. (Source: USCG)

6.2.16.4. All inspections were conducted visually and did not include the use of sounding hammers or probing tools. Further, the mate had not witnessed sounding hammers or probing tools used during any mast inspection on any vessel previously employed.

6.2.16.5. While the operator required daily/monthly rig inspections, no formal inspection expectations were established, including scope or procedures. Although the operator required inspections to be recorded in the rig log, specific record keeping requirements were not established.

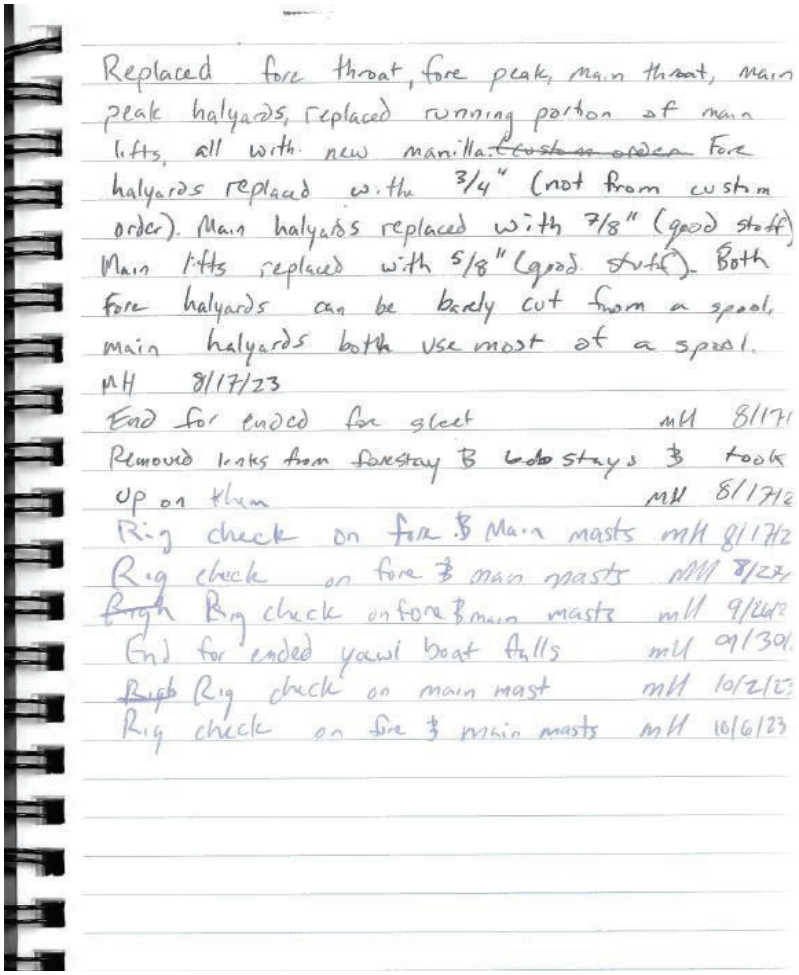

Replaced fore throat, fore peak, main throat, main peak halyards, replaced running portion of main lifts, all with new manilla. ~~Cost a order~~ Fore halyards replaced with 3/4" (not from custom order). Main halyards replaced with 7/8" (good stuff) Main lifts replaced with 5/8" (good stuff). Both fore halyards can be barely cut from a spool, main halyards both use most of a spool.
MH 8/17/23
End for ended for sheet MH 8/17
Removed knots from forestay & both stays & took up on them MH 8/17/2
Rig check on fore & Main masts MH 8/17/2
Rig check on fore & main masts MH 8/27
~~Both~~ Rig check on fore & main masts MH 9/26?
End for ended yawl boat falls MH 09/30
~~Both~~ Rig check on main mast MH 10/2/23
Rig check on fore & main masts MH 10/6/23

Figure 16 - GRACE BAILEY Rig Log entries comprising entirety of logbook. The first entry was made on August 17, 2023, with subsequent entries on August 27, September 26, September 30, October 2, and October 6. (Source: USCG)

6.2.16.6. On August 17, 2023, the mate replaced several rigging components and conducted a rig check. The inspection and the work that was completed comprise the first entry in the rig log that was required to be kept.

6.2.16.7. Subsequently, on August 27, September 26, October 2, and October 6, 2023, the mate logged rig checks on the fore and main masts, but the rig log lacked details regarding the scope of the inspections, or any conditions found.

7. Analysis

7.1. Material Specifications.

7.1.1. The mainmast and foremast were purchased and installed in 1993 after the Coast Guard issued a requirement to replace the foremast in 1991. This led to extensive correspondence between the owner and the Coast Guard from 1991 to 1993, resulting in a comprehensive record of the new mast's material specifications, which would not typically be maintained by the Coast Guard.

7.1.2. In March 1992, the owner made a purchase agreement with a PNW lumber supplier for four new masts. In this agreement, the owner specified the masts should be made from air-dried straight grain Douglas fir. Additionally, the owner stipulated that material should have at least six annual growth rings per inch, knots should be well-scattered and not exceed 1 ½" in diameter, the material should be free of conk and rot, and it should consist solely of heartwood without any sapwood.

7.1.3. In June 1992, the supplier informed the owner that the material for the masts had been located and lathe turned. However, in August 1992, a third-party inspection arranged by the owner revealed deviations from the desired specifications. In November 1992, the owner personally inspected the material and confirmed these deviations, which included deficiencies in annual growth ring count, sapwood on the upper portion of the mast, and issues with knot size and spacing. Additionally, since air-dried material was unavailable, the material was kiln-dried instead. Despite these discrepancies, the owner proceeded with the purchase and accepted delivery of the masts in May 1993. While some sapwood remained, it should be noted that this condition was limited to minor streaking and was subsequently removed during final mast shaping.

7.1.4. Annual growth rings represent the wood growth a tree undergoes within a single growing season. They consist of two parts: earlywood and latewood. Earlywood forms during the beginning of the growing season and is less dense and mechanically weaker than latewood, which forms after earlywood formation stops. Latewood is denser, mechanically stronger, and contains a higher ratio of resin deposits, offering some natural anti-fungal properties to the wood. As the size of annual growth rings increases, the ratio of earlywood to latewood also increases, resulting in wood of decreasing density,

mechanical strength, and potentially greater susceptibility to decay.

7.1.5. Post-casualty assessments confirmed that the mainmast had fewer than six annual growth rings per inch, with visible internal material containing four to five growth rings per inch. In NVIC 02-16, the Coast Guard recommended that solid/grown Douglas fir masts should have no fewer than six growth rings per inch. Although the Coast Guard did not provide guidance on Douglas fir growth rings until 2016, the six-ring per inch standard has been a well-established best practice in multiple industries for decades. Importantly, the six-ring per inch standard aims to ensure that the material meets its assumed mechanical strength properties rather than achieving a minimum decay resistance specification.

7.1.6. Although numerous published standards classify Douglas fir as moderately resistant to decay, it is widely acknowledged that without adequate seasoning and application of anti-fungal preservatives, Douglas fir timbers and poles are prone to decay, which can significantly reduce their service life.

7.1.7. The investigation revealed that some individuals in the sailing vessel community, including marine inspectors, perceive Douglas fir as resistant to decay, with heartwood being more resistant than sapwood. While these perceptions suggest that a mast made entirely of Douglas fir heartwood is adequately shielded from decay, the reality is different. Without a properly treated shell of sapwood, heartwood remains vulnerable to fungal infection and decay, as seen in the masts of GRACE BAILEY, which lacked sapwood and preservative treatment.

7.1.8. Seasoning is a crucial process that reduces moisture content and lowers the risk of decay. Douglas fir can be effectively seasoned through air drying or kiln drying. The optimal internal moisture content typically falls below 20%, although this can vary depending on the tree species. Moreover, the target moisture content varies by geographic region due to the wood's equilibrium moisture content being influenced by the relative humidity and temperature of its surroundings. During the investigation, certifiable documentation confirming the seasoning method (air dried/kiln dried) could not be found. However, documentary evidence and witness testimony from the previous owner indicates that the material was kiln dried. Unfortunately, specific details such as kiln temperature and final moisture content remain unknown. This lack of certifiable documentation raises questions about the quality and durability of the mast material.

7.1.9. Extensive studies have been conducted on anti-fungal preservative treatment methods for Douglas fir timbers and poles. Although not formally adopted by the Coast Guard, approved treatment methods for Douglas fir timbers and poles are well-established. According to the USFS FPL Wood Handbook, Douglas fir heartwood offers limited decay resistance and is resistant to anti-fungal preservative penetration. Therefore, Douglas fir poles need a well-treated shell of sapwood, free of checking, to ensure pole durability. It's

recommended that Douglas fir poles be adequately seasoned before preservative treatment to minimize post-treatment checking. Additionally, the United States Department of Agriculture Bulletin 1728F-700 (Rural Utility Service Specification for Wood Poles, Stubs, and Anchor Logs) provides guidance on preservative penetration for various species. According to this guidance, treatment of Douglas fir poles should penetrate to a minimum depth of ¾" and cover 85% of the sapwood.

7.1.10. The investigation team largely confirmed deviations from the purchase specifications. The mast indeed lacked the specified annual ring count, which is crucial for mechanical strength properties, but doesn't necessarily prove enhanced risk of decay. While the material was kiln dried instead of air dried, kiln drying is a widely accepted practice that, if conducted properly, does not harm the wood. The investigation could not determine if the seasoning method and resulting material conditions were a causal factor to the casualty. Knot clusters were identified near the break point, but they were surrounded by severely rotted material and are not believed to have contributed to the failure. The only specification that wasn't deviated from in the purchase request was the removal of all sapwood. Since a well-treated sapwood shell is essential for Douglas fir decay resistance, it is believed that this condition contributed to the internal decay of the mast.

7.2. Fungal Infection and Progression of Decay.

7.2.1. Certain elements must be simultaneously present to support the propagation and growth of wood decaying fungus, including adequate moisture content, available oxygen, favorable temperatures, and food.

7.2.2. Adequate moisture content can vary based on fungal species, but generally, wood moisture content below 20% will not support fungal growth. The primary limiting factor for oxygen availability can be loosely attributed to moisture content, where saturated wood will not contain adequate oxygen to support fungal growth, for example, fully submerged portions of marine piles are rarely deteriorated by fungal decay. Temperature suitable for growth varies with fungal species, but most show optimal growth at 77°F with minimum and maximum temperatures of 41°F and 104°F. Growth is usually slow below 50°F and above 95°F and generally ceases below 35°F and above 100°F.

7.2.3. Decay fungi are broadly grouped as brown rot or white rot fungi, with the primary distinction being the portion of the wood cell that is consumed by the fungus, brown rots consume cellulose and white rots consume lignin. While the mechanism of decay differs, the result is the same, a significant reduction in the mechanical strength properties of the wood. Samples of the mast were collected and cultured by USFS FPL, revealing the decay fungus to be *Antrodia xantha*, a known brown rot fungus.

7.2.4. Studies have examined the fungal infection rate of lumber in PNW lumber seasoning yards, and the prevalence of decay fungi found. The results revealed

that 54% of peeled air-seasoned poles were colonized by decay fungi within six months, 72% within 12 months and 93% within 18 months. While the rate of decay fungi colonization ranged from 54% to 93%, *Antrodia xantha* was detected in only 2% of the samples, making it one of the rarer species identified. However, additional studies aimed to quantify strength losses caused by decay fungi found *Antrodia xantha* to be among the most severe wood decay fungi studied.

7.2.5. Another study aimed to measure the growth rates of various decay fungi, including *Antrodia xantha*. It revealed that *Antrodia xantha* grows at a rate of 3.7 mm/day to 5.5 mm/day. Specifically, the growth rate was found to be 3.7 mm/day at 71.6°F, 4.5 mm/day at 77°F, 5.1 mm/day at 82.4°F, 5.5 mm/day at 87.8°F, and 4.4 mm/day at 93.2°F.

7.2.6. The mainmast of GRACE BAILEY exhibited signs of rot along a 48-foot section, starting 12 feet above the base and extending upwards to 60 feet above the base. Given the maximum growth rate of *Antrodia xantha*, it would take approximately 7 ½ years for the rot to spread across this section. Conversely, at the minimum growth rate, it would take nearly 11 years. However, these estimates don't factor in the seasonal climate of the vessel's operating area.

7.2.7. In Rockland, ME, where the vessel operates, the average daily temperature rarely supports the maximum growth potential of *Antrodia xantha* (87.8°F). Even reaching an average daily temperature to support the minimum recorded growth rate (71.6°F) is uncommon, especially during late fall, winter, and early spring (November-March).

7.2.8. To assess the time for observed rot to develop, investigators considered the maximum, average, and minimum growth rates during the period when the average temperature exceeds 40°F (April-October, 210 days) and 50°F (May-September, 150 days). Additionally, investigators calculated the growth rate required for the rot to spread to the observed conditions over the mast's service life at these temperatures.

Growth Rate	Time to condition assuming growth occurs above 40°F	Time to condition assuming growth occurs above 50°F
5.5 mm/day (maximum rate)(87.8°F)	12.6 years	17.7 years
4.05 mm/day (average rate)(82.4°F)	17.7 years	24.1 years
3.7 mm/day (minimum rate)(71.6°F)	18.8 years	26.3 years
3.26 mm/day (rate to cover 48' in 30 yrs with growth occuring above 50°F)	21 years	30 years
2.32 mm/day (rate to cover 48' in 30 yrs with growth occuring above 40°F)	30 years	42 years

Figure 17 – Antrodia Xantha probable growth rates, reflective of environmental conditions in GRACE BAILEY *operating area. (Source: USCG)*

7.2.9. It's reasonable to assume that fungal growth occurred between April and

October at a rate lower than the minimum rate identified in the growth study. Considering the climate-induced growth limitations and the extent of fungal propagation, it's also reasonable to assume that the mast was infected prior to delivery.

7.2.10. The extensive timeline required for *Antrodia xantha* to propagate to the extent present in the GRACE BAILEY mainmast is evident. It's also clear that high moisture content, necessary to support rot propagation, must have been present throughout the entire growth period. Whether the mast was improperly seasoned and delivered with high moisture content, or if moisture intrusion occurred shortly after delivery, cannot be confirmed. However, even if it was delivered with high moisture content, without additional moisture intrusion throughout its service life, the mast would have continued seasoning in place, eventually reaching its equilibrium moisture content, which is well below the level needed to sustain continuous rot.

7.2.11. The pattern of internal rot identified through stress wave time of flight (ToF) and resistance drill measurements (see enclosures 4 and 5) aligns with locations of numerous deep and surface checks along the mast exterior. It's believed that each of these checks contributed to moisture intrusion to some extent over the mast's service life.

7.3. Prior Owner/Operator Preservation, Maintenance, and Inspections (1993-2022)

7.3.1. **Lack of a formal maintenance and inspection program.** The vessel's prior owner did not have a formally established mast maintenance or inspection program in place. This absence of a structured program meant there was no systematic approach to monitor the condition of the masts. The lack of a formalized routine contributed to unidentified degradation of the mast over time.

7.3.2. **Limited mast maintenance.** Mast maintenance was limited to bi-annual slushing performed by the crew. While slushing can help protect the mast from moisture and decay, it is insufficient on its own to address underlying structural issues. Without thorough inspections accompanying the slushing, deterioration went unnoticed and unaddressed.

7.3.3. **Limited crew training.** Crew members were expected to inspect the masts visually during bi-annual slushing. However, they were not trained in specific mast or wood inspection procedures. This lack of training and knowledge meant that inspections were superficial, and crew members were not equipped to identify deeper structural issues.

7.3.4. **Visual observations without proper tools.** The limited mast inspections conducted by crew members were primarily based on visual observations, which resulted in superficial assessments. The crew did not utilize phenolic hammers for sounding, moisture meters, or probing tools that would extend to the deepest recesses of a check, all of which make up current "industry established best practice". The absence of traditional wood assessment tools increased the likelihood of structural issues being overlooked.

7.3.5. **Lack of documentation.** There was no documentation for inspections conducted by the crew. The absence of documented records hindered traceability and accountability. This lack of documentation made it challenging for the owner to track the vessel's maintenance history, identify trends, and ensure proactive correction of underlying structural deficiencies in the masts.

7.3.6. **Reliance on Coast Guard inspections.** The prior owner primarily relied on inspections by the Coast Guard, conducted annually and at 10-year intervals. The Coast Guard holds statutory authority and responsibility to establish and execute vessel inspection procedures (see 6.2.4.1). While these external inspections provided some oversight, their limited frequency meant they could not capture all potential issues and identifiable flaws between inspections. While the Coast Guard is required to carry out statutory inspection requirements, masters, owners, or other responsible parties are required by statute to maintain inspected vessels to always be in compliance with applicable regulations, which includes maintaining the vessel in accordance with industry standards and good marine practice. (see 6.2.4.2).

7.3.7. **Preference to leave mast checks open.** The prior owner preferred to leave mast checks open, intending to prevent water entrapment and promote drainage. However, post-casualty evaluations revealed that most of these checks were filled with a wax/oil-based material, rendering the intention to promote proper drainage ineffective and potentially concealing underlying issues.

7.4. Current Owner/Operator Preservation, Maintenance, and Inspections (2022-2023)

7.4.1. **Delegated responsibility and limited training of the mate.** The operator delegated responsibility for mast and rigging inspections to the mate. Although the mate had prior experience, they lacked formal training in mast and wood inspection. This delegation without proper training led to several issues. While the mate conducted inspections monthly, the absence of formal training and adequate guidance likely compromised the thoroughness and accuracy of these assessments. Inspections were conducted visually without the use of sounding hammers or probing tools. This limitation meant that underlying structural issues, such as internal rot or decay, could go undetected, increasing the risk of mast failure.

7.4.2. **Inadequate documentation and record-keeping.** The vessel's mast maintenance and inspection documentation practices were notably inadequate. There were no specific record-keeping requirements, leading to inconsistent logging of inspections. The logs that were kept lacked detailed information regarding the scope of inspections, findings, and the conditions observed. This inconsistency limited the utility of the records for tracking maintenance history and identifying emerging issues.

7.4.3. **Insufficient oversight and reporting.** There was a lack of oversight and formal reporting mechanisms related to the operator’s internal mast inspection

processes. Inspections were not adequately documented, and there were no formal expectations set for reporting inspection findings. This lack of oversight likely contributed to delayed or inadequate responses to emerging issues, allowing hazards to persist and escalate unchecked.

7.4.4. **Reliance on Coast Guard inspections.** As with the prior owner, the current owner relied on inspections by the Coast Guard, conducted annually and at 10-year intervals (see 7.3.7, 6.2.4.1, and 6.2.4.2).

7.5. Engagement of Professional Marine Surveyor

7.5.1. Both the current and prior owners of the GRACE BAILEY engaged a professional marine surveyor to inspect the vessel, including its masts and rigging. This engagement aimed to obtain an expert assessment on the vessel's condition, maintenance needs, and compliance with regulatory standards. While their involvement was primarily to establish an appraisal value, the surveyor's inspections also captured details reflecting the safety and seaworthiness of the GRACE BAILEY.

7.5.2. **Expertise and qualifications.** The marine surveyor possessed specialized knowledge, training, and certifications pertinent to vessel inspection, maritime regulations, and industry best practices. Despite not performing an aloft inspection, their qualifications enabled them to accurately evaluate the GRACE BAILEY*'s* mast and rigging from accessible areas. This expertise assured confidence in their findings and recommendations, albeit within the limitations of the inspection methodology.

7.5.3. **Surveyor's inspection process.** The inspections focused on areas that were readily accessible without going aloft. Although the surveyor could not directly assess inaccessible parts of the mast, their inspection process allowed for the identification of visible issues with the vessel's foremast.

7.5.4. **Documentation and reporting.** After the inspection, the surveyor documented their findings, observations, and recommendations in comprehensive inspection reports. The reports included detailed documentation of the visible condition of the masts and rigging. This detailed documentation provided valuable insights for both the current and prior owners, aiding in decisions regarding maintenance, repair, or replacement initiatives within the scope of the accessible inspection areas.

7.5.5. While the marine surveyor is not constrained to a deck level visual examination of the masts and rigging, unless an aloft inspection is specifically requested or purchased by the customer, mast and rigging inspections conducted by the surveyor do not expand beyond a visual examination from the deck. Neither the current nor previous owner of GRACE BAILEY requested an aloft inspection. Had they done so, it is highly probable the surveyor would have identified material deficiencies present in both masts.

7.6. Coast Guard Inspections

7.6.1. **Inspection standards.** The Coast Guard holds primary responsibility for establishing and enforcing inspection standards to ensure the structural integrity and safety of vessels holding a COI. This includes establishing regulations and standards for the inspection of masts. Periodic inspections are conducted to verify compliance with applicable safety regulations.

7.6.2. **Marine inspector training.** The Coast Guard provides guidance and training to its inspectors on conducting wood and sailing vessel inspections, including the use of appropriate techniques and tools. The marine inspectors at MSD Belfast met all training and knowledge requirements outlined in Coast Guard policies and held all relevant certifications for the completion of this work. While the techniques marine inspectors are trained to align with industry best practices, implementation of the techniques toward mast inspections is largely hindered by mast accessibility and reliance on visual examinations from deck level.

7.6.3. **Inspection frequency, scope, and procedures.** Periodic inspections are scheduled to assess the condition of vessel masts and rigging systems. Regulations require that masts be inspected annually. Additionally, guidance in NVIC 02-16 recommends wood masts undergo an unstepped inspection at 10-year intervals. By policy, these inspections may include visual assessments, non-destructive testing, and any other test deemed appropriate by the marine inspector to verify compliance with applicable regulations and standards. While Coast Guard training and qualification standards include the use of traditional assessment tools, including sounding hammers and probes, annual examinations of the GRACE BAILEY*'s* masts were limited to a visual examination from deck level. Visual inspections, while essential, have inherent limitations in identifying hidden defects or degradation, such as internal rot or structural weaknesses.

7.6.4. **Conducting inspections aloft.** By Coast Guard and OSHA policy, Coast Guard personnel are required to complete specialized training and be provided with personal protective equipment and engineered safety controls before they are authorized to work at heights. These measures, amongst many others, are required to be formalized in a Fall Protection Plan (FPP) under the direction of the requisite Sector Commander. Absent implementation of an FPP that authorizes marine inspectors to work at heights aboard vessels, including conducting aloft inspections, they are specifically prohibited from doing so. Sector Commanders have no control over climbing equipment and fall protection attachment points on vessels subject to Coast Guard inspection. As such, development of an FPP that ensures the safety of marine inspectors conducting aloft inspections is challenging. These safety requirements and the resultant accessibility issues are a limiting factor in Coast Guard mast inspection procedures and are the primary reason that annual inspections are limited to a visual examination from the deck (see 6.2.6.12).

7.6.5. **NVIC 02-16.** NVIC 02-16 acknowledged that marine inspectors are not

expected to go aloft, as the Coast Guard does not provide personal protective equipment needed to do so. As an alternative, the NVIC steers marine inspectors towards the use of binoculars or other visual aids to examine the masts. If an area of concern is noted with visual aids, it is incumbent on the owner to conduct further examination to verify the condition. Up close visual assessment of the masts during post casualty assessment did not reveal any outward indicators of deterioration. As such, the probability of identifying deterioration in GRACE BAILEY*'s* masts using visual aid tools as recommended by the NVIC is low. The NVIC also notes that marine inspectors can use various lift cranes if provided by the operator. However, annual inspections are generally completed at the vessel's berth and are not conducive to crane access. NVIC 02-16 inspection guidance reinforces the use of visual inspections as the primary means of mast inspection, where the results of the investigation reveal visual inspections of GRACE BAILEY*'s* stepped masts to be of limited value.

7.6.6. **Coast Guard reliance on owner, operator, and third-party reports.** MSD Belfast inspectors reported historic reliance on owners, operators, and third-party surveyors to identify and report rotted conditions in masts. This does not mean that MSD Belfast delegated mast inspections to other entities. Rather, it means despite the annual inspections conducted by MSD Belfast, all rotted mast conditions captured in permanent records were identified by another entity and reported to the Coast Guard, rather than being found by Coast Guard inspectors. Historic mast deficiency reporting by owners, operators and surveyors reflects positively on inspector collaboration with industry professionals, but this approach falls short when owners are not diligent in their internal assessments.

7.6.7. **Efficacy of traditional inspections during 10-year un-stepped inspections.** The GRACE BAILEY masts were unstepped for inspection and repairs in 2014. Coast Guard records for the activity focus entirely on oversight of repairs, and do not mention the completion of an inspection. As such, it cannot be confirmed if Coast Guard inspectors physically assessed the masts using traditional testing methods at that time, or what the results of any inspection they conducted was. Wood wrights involved in the repair confirmed they assessed the mast using traditional methods and were confident that no indications of rot beyond the repaired locations was found. Given the growth rate of the fungus involved, combined with the known environmental growth limitations, it is highly probably that incipient and advanced decay were present at numerous internal locations along the mast. It is believed the decay was deep enough below the surface that hammer tapping was ineffective in locating it. This aligns with findings during post casualty analysis, where ToF and resistance drill measurements clearly indicated extensive internal decay that could not be located with hammer tapping. While visual examination and hammer tapping have long been the established inspection standard, the investigation results indicate that inclusion of various non-destructive testing techniques during inspections will provide superior condition assessments.

7.6.8. **Overall efficacy of Coast Guard mast inspection procedures.** Coast Guard mast inspection procedures were insufficient for detecting rotted conditions in GRACE BAILEY*'s* masts. Current procedures heavily rely on visual examinations, only incorporating other traditional methods such as hammer tapping at 10-year intervals or when external flaws are visually observed. In the case of GRACE BAILEY, no obvious external conditions that would prompt further evaluation were present. Additionally, comparing hammer tapping results against technology-based assessments revealed the traditional method was inferior at detecting internal decay. Since wood strength can be significantly compromised, up to 50%, at the incipient stage of fungal decay, any limitation in inspection techniques is critical. With GRACE BAILEY, early degradation went undetected and progressed to more advanced, and thus more dangerous, stages. While the observed inadequacies in these methods are only directly attributable to GRACE BAILEY, they indicate that improved detection capabilities for inspectors and owners would provide a significant safety benefit for all similar vessels.

7.6.9. **Documented trend analysis.** Inconsistent documentation of mast and rigging inspections hinders the tracking of mast conditions over time and the identification of patterns or trends related to mast rot. Comprehensive and standardized documentation is essential for effective risk management and regulatory compliance. The Coast Guard's MISLE database and Coast Guard Business Intelligence (CGBI) systems currently lack dedicated data entry points for mast inspections and deficiencies, making it difficult to compile and analyze mast inspection data and trends effectively. Improved data analysis can enable the identification of patterns or trends related to mast rot, facilitating proactive regulatory interventions.

7.6.10. **Communication and collaboration.** The Coast Guard collaborates with industry stakeholders, including vessel owners/operators, maritime associations, and classification societies, to promote awareness of safety regulations and best practices. Sharing information and lessons learned from incident investigations enhances safety awareness and improves regulatory compliance within the maritime community. The findings of this investigation highlight the need for further collaboration on mast inspection processes, procedures, and requirements.

7.6.11. **Policy review and revision.** The Coast Guard continuously reviews and updates its policies and inspection standards based on evolving industry practices, technological advancements, and lessons learned from past incidents. The results of this investigation reveal review and revision of mast inspection procedures is prudent.

7.6.12. **Material condition.** Wooden masts are prone to rot, weathering, and other forms of degradation over time, which compromises their integrity and strength. Inadequate protection, treatment, and inspections allowed undetected rot to spread throughout the GRACE BAILEY mainmast, ultimately leading to failure.

7.6.13. In the earliest stage of decay, known as incipient decay, wood strength can be

reduced as much as 50%. Without fungal culturing, incipient rot is nearly undetectable. However, both masts on GRACE BAILEY exhibited severe rot throughout their lengths. Despite no obvious visual signs, the rot had progressed well beyond the incipient stage and was easily detectable at various locations on the masts using traditional inspection techniques during unstepped post-casualty evaluation. Additionally, technology-based assessments provided a clear picture of the severely degraded conditions along the entire length.

7.6.14. Given the observed mast conditions and assumed fungal growth rates, it is clear that rot had existed for several years. Although the masts were unstepped and underwent significant repairs in 2014, it is highly probable that additional rotted areas were present and detectable with various technology-based assessment tools. It is also likely that internal rot was deep enough to evade detection with traditional inspection procedures and tools.

7.6.15. **Standing and running rigging.** Despite thorough assessments, no anomalies were identified in the standing or running rigging, and their condition was not found to be a causal factor. This contrasts with previous demasting incidents, where rigging condition and arrangement were predominant causal factors.

7.6.16. **Environmental and operational stress.** Sustained winds and gusts between 16-28 mph over the preceding days continuously stressed the mast. However, these conditions were not unusual for the operating area, and proactive sail management, such as reefing when appropriate, was performed throughout the voyage. Frequent changes in sail configuration and tacking maneuvers subjected the mast to varying dynamic loads and stresses, but the vessel operated normally throughout the voyage. While these stresses contributed to the mast failure, it is important to note that without the severely deteriorated masts, the environmental and operational conditions would not have caused material failure.

7.6.17. **Audible warnings.** During witness interviews, two passengers reported hearing unusual noises from the mast before its failure. One passenger heard noises about an hour before, and another heard noises about a minute before. While both passengers found the noises odd, they did not find them significant enough to report to the crew. Although it was not the passengers' responsibility to recognize audible warnings as signs of stress or cracking, the lack of reporting was a missed opportunity to detect and address the hazard. A third audible warning, heard by multiple passengers and crew members, immediately preceded the mast collapse. Moments before the collapse, the captain and mate observed signs of failure and warned passengers to get clear of the mainmast. Unfortunately, the warning came simultaneously with the mast's fall, leaving no time for passengers to get clear of the collapsing rig.

7.7. Emergency Response

7.7.1. **Prompt communication.** The immediate and clear communication between GRACE BAILEY and STA Rockland was crucial in initiating a swift SAR response. The captain's prompt distress call allowed the Coast Guard to

mobilize resources quickly.

7.7.2. **Effective coordination.** STA Rockland and Sector Northern New England's ability to coordinate with local assets like Charlie's Marine enhanced the effectiveness of the SAR operation. Continuous updates and coordination ensured that all parties were informed, and actions were synchronized.

7.7.3. **Deployment of rescue assets.** The deployment of CG-47256 was timely and appropriate for the conditions. The vessel's crew was prepared to complete evacuations under challenging circumstances.

7.7.4. **Medical assistance and evacuation**. On-scene medical assistance provided by passengers with emergency medical training was critical for managing the immediate needs of injured passengers. Rapid evacuation ensured that injured individuals received necessary care quickly. Tragically, the severity of one passenger's injuries required advanced care beyond the capabilities of the on-scene responders. Despite STA Rockland's prompt evacuation of the passenger, approximately 20 minutes post-incident, and observation by shoreside EMTs around 32 minutes post-incident, advanced emergency care was needed immediately upon injury. While the efforts of STA Rockland, on-scene responders, good Samaritans, and shoreside EMTs were swift, efficient, and highly commendable, they were simply not equipped to provide the necessary level of medical care that the passenger required.

7.7.5. **Multi-agency collaboration.** The collaboration between the Coast Guard, local EMTs, Charlie's Marine, and the captain of GRACE BAILEY highlighted the importance of multi-agency efforts in SAR operations. This teamwork enabled resource sharing and enhanced response capabilities.

8. Conclusions

8.1. **Determination of Cause:** The investigation team identified the following series of events and associated contributing factors.

8.1.1. **Material failure and collapse of the mainmast.**

8.1.1.1. **Severe internal rot.** The mainmast exhibited extensive internal decay due to fungal growth. This rot significantly weakened the structural integrity of the mast, making it prone to failure under stress.

8.1.1.2. **Material selection.** Unlike pole and pile material specification guidance used in other industries, which mandates that Douglas fir poles include a treated sapwood shell to shield the heartwood from decay, the masts of GRACE BAILEY had almost all sapwood removed during lathing. Additionally, the remaining sapwood at the upper portion of the mast was removed during final shaping.

8.1.1.3. **Failure to implement effective preservative treatment.** A properly treated sapwood shell is essential for preventing decay in

grown Douglas fir masts. This entails pressure treatment following proper seasoning to ensure that the interior of seasoning checks receives the necessary treatment. GRACE BAILEY*'s* masts did not undergo anti-fungal treatment, leaving heartwood unprotected from fungal colonization. Checks, ideally limited to a treated sapwood shell, penetrated unprotected heartwood, allowing continual moisture intrusion into the mast interior. Slush provided some level of protection to the exterior surfaces but offered little defense against moisture intrusion into numerous deep mast checks.

8.1.1.4. **Significant and sustained moisture intrusion.** Commonly used chemical treatments not only imbue wood with anti-fungal properties but also create a barrier against moisture intrusion. While slush offers some protection to a mast's exterior, pressure-treated sapwood proves highly effective in preventing moisture from penetrating the wood's interior.

8.1.1.5. **Inadequate external inspection methods and procedural limitations.** The Coast Guard's inspection methods lacked depth due to safety constraints, primarily relying on visual inspections from deck level. Alternative methods like lift cranes, as advised by NVIC 02-16 were not used. Although neither the current or previous owner had a formally established PMP, there is no record indicating the Coast Guard ever required a 3rd party rig survey as noted in NVIC 02-16. Coast Guard inspectors expressed that owner, operator, and third-party reports are the predominant means of identifying mast decay. This collaborative approach strengthens partnerships and nets positive inspection results. However, in the absence of dedicated owner/operator protocols, accurate Coast Guard assessments are needed. Inconsistent documentation and a lack of dedicated data entry points hinder analysis and trend identification.

8.1.1.6. **Inadequate internal inspection methods and training.** The owners'/operators' internal inspection programs and crew training were insufficient, resulting in superficial maintenance practices. Limited crew training led to surface-level inspections, lacking tools and documentation for deeper structural assessments. Reliance on infrequent Coast Guard inspections further exacerbated the issue, emphasizing the need for enhanced internal protocols and crew training to proactively address mast-related issues.

8.1.2. **Six passengers struck and injured by falling debris.**

8.1.2.1. **Missed audible warnings.** Audible warnings were detected one hour, one minute, and just before the mast collapsed. Passengers, understandably, may not recognize creaking wood and rigging as potential hazards. While operators can include extensive

information in passenger safety briefings, such as urging passengers to report unusual noises to the crew, it's unrealistic to expect all safety hazards, especially extremely rare ones, to be effectively communicated.

8.1.3. **Loss of life.**

8.1.3.1. **Emergency response capabilities and limitations.** The capabilities and limitations of first responders played a critical role in the outcome of the incident. Despite their prompt and commendable efforts, the severity of one passenger's injuries required immediate advanced medical intervention far exceeding their capabilities. While Coast Guard and EMT coordination provided a swift evacuation, the delay in essential emergency medical treatment proved insurmountable. The gap between the injury occurrence and transport to advanced medical support contributed to the fatal outcome.

9. Recommendations

9.1. Safety Recommendations:

9.1.1. **Recommendation #1 –** It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to identify wooden mast material characteristics and conditions that can precede, influence, or contribute to fungal decay. In addition to those items listed in NVIC 02-16 Appendix (10) to Enclosure (1) and NVIC 07-95 Chapter 4, potentially relevant characteristics, and conditions, amongst many others, might include species, age, geographic harvest region, seasoning method and results, preservative treatment type and method, area of operation, moisture intrusion points and moisture content, and previous decay.

9.1.2. **Recommendation #2 –** It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to determine which, if any material characteristics identified by Recommendation #1 can be reasonably monitored as part of a Preventive Maintenance Plan. Where feasible, develop inspection and documentation guidance to assist owners and inspectors with detecting and recording changes or stability of these conditions over time.

9.1.3. **Recommendation #3 -** It is recommended that Commandant direct policy and/or guidance updates to require the collection and standardized recording of wooden mast material characteristics and conditions identified by Recommendation #1 within a vessel's permanent MISLE record. Additionally, stability or changes of those items which can be reasonably evaluated as determined by Recommendation #2 should be recorded in a standardized format following each inspection. NVIC 02-16 Enclosure (1) III.a.iv.1 already requires marine inspectors to provide a "Detailed description of the rig and associated gear" within MISLE or a vessel's permanent file

upon completion of an annual exam. The intent of this recommendation is to provide wood mast specific guidance to supplement this record keeping requirement and to ensure that all potentially hazardous mast conditions are evaluated at each inspection.

9.1.4. **Recommendation #4 –** It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL, to evaluate non-destructive testing technologies, including internal moisture detection, and determine which, if any, are suitable for wood mast inspections. It is further recommended that Commandant direct a review of the newly formalized sail and rigging course for marine inspectors, course code 100439, and update as necessary to ensure all suitable non-destructive testing methods and their appropriate uses are adequately covered.

9.1.5. **Recommendation #5 –** It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to assess the current 10-year unstepping interval guidance for wood masts in NVIC 02-16 and revise if warranted.

9.1.6. **Recommendation #6 –** It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to evaluate industry established best practices for conducting wood mast inspections. This information should be consolidated, revised if necessary, and distributed to commercial sail vessel operators and marine inspectors by the most efficient means available.

9.1.7. **Recommendation #7 –** It is recommended that Commandant direct broad collaboration with sailing industry organizations such as Tall Ships America, as well as marine surveyors and USFS FPL to review existing training guidance for crew members who are involved with wood mast inspections. This information should be consolidated, revised if necessary, and distributed to commercial sail vessel operators and marine inspectors by the most efficient means available.

9.1.8. **Recommendation #8 –** It is recommended that Commandant direct a review of Preventive Maintenance Plan implementation status across the Coast Guard, track industry achievement of the recommended practices, and initiate outreach to improve adherence if warranted.

9.1.9. **Recommendation #9 –** It is recommended that Commandant direct a review of MISLE vessel deficiency data entry fields and update to ensure that mast inspections, deficiencies and repairs are adequately captured and recallable for data analysis. The addition of “Mast” as a subsystem of “Sail Rigging”, or the addition of “Mast” as a component of the sub-system “Spars” might achieve this. Alternatively, guidance directing marine inspectors to capture all mast specific deficiencies under a specified data field that already exists could be developed.

9.2. Administrative Recommendations:

9.2.1. Award Recommendation - It is recommended that Coast Guard District One consider appropriate recognition for GRACE BAILEY passengers and Good Samaritans who provided immediate emergency medical response for injured persons.

9.2.2. Based on the findings of this investigation, it is not recommended that any administrative or punitive action be taken against any Coast Guard personnel. It is not recommended that suspension or revocation action be taken against any credentialed mariner. Additionally, it is not recommended that criminal prosecution be taken against any person or entity.

Commander, U.S. Coast Guard
Investigating Officer

Enclosures: (1) Condition Assessment Report, USFS FPL
(2) Post Casualty Material Analysis

Condition Assessment of GRACE BAILEY **Masts**

— **A Field Inspection Report**

Submitted to

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April 5, 2024

Condition Assessment of GRACE BAILEY Masts

Background

In response to a request from Mr. [redacted] and LT [redacted] of the United States Coast Guard, USDA Forest Service Forest Products Laboratory staff traveled to Rockland, ME on December 18-20, 2023, to conduct an on-site assessment of the GRACE BAILEY masts using nondestructive testing techniques frequently used with timber structures. The objective of our on-site assessment was to provide quantitative information regarding the current physical condition of the mast and identify possible causes that led to its catastrophic in-service failure.

The species of wood of this mast is Douglas-fir (*Pseudotsuga menziesii*). Douglas-fir is native to western North America and is frequently used in a variety of structural applications. The mast is a 70-ft-long solid timber that was milled to approximately 18 in. diameter at base and 16-in. diameter at top. Our on-site investigation was primarily focused on the failed mast that had been taken down and stored inside a storage facility in Rockport, ME.

Inspection Methods

Inspection methods employed in this investigation included visual, stress wave scanning, resistance micro-drilling, and fungal identification. Stress wave scanning and resistance micro-drilling are the state-of-the-art nondestructive testing techniques for assessing internal physical conditions of wood structures (Forest Products Laboratory 2000; White et al. 2014). These NDT techniques have been used by the team to conduct condition assessment in many historic structures, including wooden ships ─USS Constitution (Ross et al. 1996); C.A. Thayer (Wang et al. 2001); Highlander Sea (Wang and Wacker 2006a); U.S. Brig Niagara (2006b); Wapama (Wang et al. 2008); and Minnehaha (Brashaw et al 2009). They are used by inspection professionals worldwide for inspecting many types of historic artifacts and timber structures. The following briefly describes each of the techniques we used.

Stress wave scanning

Stress wave scanning (stress wave/sound transmission) techniques 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. The underlying premise is that stress waves travel 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 condition of the wood. By measuring the time-of-flight of a stress wave travelling through a wood member (perpendicular to grain), the internal condition of the member can be determined. Detailed information on the principles of this technique, guidelines for use and interpretation, commercially available equipment, and examples of its use are given in *FPL-GTR-119* (FPL 2000) and *Wood and Timber Condition Assessment Manual* (White et al. 2014).

Resistance micro-drilling

The resistance micro-drilling tool is a 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. Detailed information on the use of resistance micro-drilling tool is given in *Wood and Timber Condition Assessment Manual* (White et al. 2010) and FPL-GTR-159 (Brashaw et al. 2005).

Inspection Procedures

To determine the extent of the internal decay in the mast, we conducted stress wave transmission measurements at a series of cross-sections of the mast using a Fakopp Microsecond Timer unit (Fakopp Enterprise, Sopron, Hungary). Measurements were taken every foot in both horizonal and vertical directions. The diagram in **Figure 1** shows the stress wave data collection points in the mast. **Figures 1I** through **1L** show the sensor probes inserted into the mast at two opposing sides to measure the time of flight. Stress wave transmission tests requires access of two opposite sides of the mast for attaching sensor probes. During the stress wave transmission measurements, diameter of the mast was measured at several locations along the mast height. The cross section of the mast was circular for most of the length and transitioned to square for the top 8 feet. The mast was broken approximately between 45 ft and 53 ft, therefore, no stress wave data was collected in that region.

Following the stress wave transmission measurements, we conducted resistance micro-drilling tests at three selected locations: 21 ft, 25 ft, and 34 ft from the base, as a verification of the stress wave measurements. Locations of resistance drilling tests are indicated as "Res. Drill" in **Figure 1**.

In addition to the physical tests, we collected decayed wood samples from five different locations in the mast, stored them in plastic bags, and brought back to FPL for fungal identification. The yellow, porous fungus present on the Douglas-fir mast were visually identified using fungal identification keys.

Observations

Photographs of the mast were taken during our on-site inspection. **Figure 1** shows photographs of mast features as well as a diagram depicting the approximate locations the photograph shows. The mast was broken approximately 20 ft from the top. Extensive, deep checks can be observed on many sections of the mast. Surface rot was observed at 5 feet and 63 feet above the mast base. Some areas near the location of the failure indicated probing tests were conducted using a pocketknife in previous investigations.

The broken top of the mast is shown in **Figure 1A**. The fracture surface is shown in **Figures 1B** to **1F**. Evidence of fungal decay is present as the white coloration in **Figures 1B, 1D,** and **1F**. **Figures 1E** and **1F** show regions of brash failure as well as cubical fracturing, both of which are evidence of fungal decay of wood. Extensive internal decay was observed within the inspection holes. **Figures 1G, 1H,** and **1I** show inspection holes created prior to the FPL inspection. The holes allowed access to the interior of the mast. Fungal decay, evidence of brash failed wood, and cubical wood remnants was visible in all three locations where the holes were created. **Figure 1J** shows the first evidence of suspect wood at approximately 21-ft from the base of the mast, which is in the middle of the scarf joint from the 2014 scarf repair. **Figure 1K** shows the condition of the mast at deck height. **Figure 1L** shows surface decay.

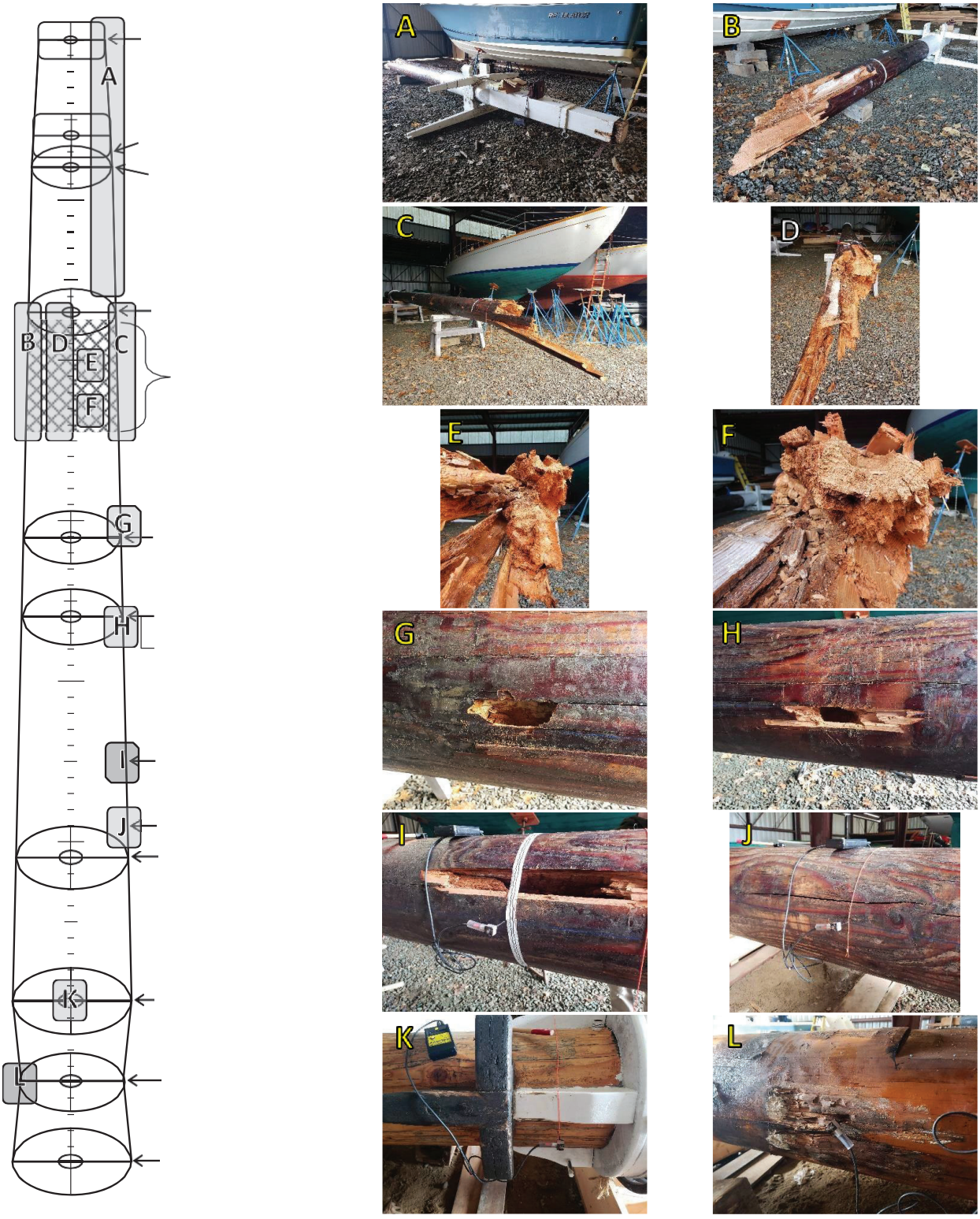

Figure 1. Documented features observed along the mast length. The diagram of the mast shows the location of each photograph. A) broken top of the mast; B-F) Fracture surface G-I) Examination holes created prior to FPL inspection; J) First observable internal decay from SWTT; K) Mast at deck height; L) Surface rot.

Results of On-Site NDE Tests

Stress wave data analysis

Figure 2 shows the distribution of stress wave transmission time, time-of-flight (ToF) expressed in μs, for the failed mast. The transmission time across the grain is normalized by the distance between the starting and stopping probes yielding common unit of μs/ft for ToF. Normal range of sound wood is less than or equal to 200 μs/ft; suspect wood is more than 200 and less than 300 μs/ft; above 300 μs/ft is indicative of decayed wood. **Figure 2** shows the ToF values by color along the length of the mast.

Measurements were taken at cross sections every 1 foot and in two perpendicular directions: from bow to stern and starboard to port. Areas of green indicate sound wood; yellow indicates suspect wood, and red indicates decayed wood. A chart of the numerical ToF values is also shown in **Figure 2** along with thresholds for sound and decayed wood. Some locations had ToF values more than 600 μs/ft, indicating severely advanced decay. The locations of highest ToF were located just above and just below the broken region of the mast. This finding supports the hypothesis that the mast broke in the region of worst decay. Severe decay was identified from the stress wave transmission measurements taken between 26 ft and 56 ft above the mast base in the Bow to Stern axis. Suspect wood ranges from 20 to 26 ft and 56 to 58 ft along the same axis. Along the Starboard to Port axis, suspect wood ranges from 24 to 56 ft with decay at 37 to 38 ft, and severe decay at 45 ft.

Results from follow-up resistance micro-drilling tests paralleled those obtained from stress wave testing. Both ToF and resistance micro-drilling indicate the presence of severely deteriorated wood.

Resistance micro-drilling

Resistance drilling is a quasi-nondestructive inspection technique. The tool uses an instrumented drill which measures driving force and torque of a specialized drill bit. The drill bit can vary in length from 8 to 14-in; the head is a paddle-bit with a ⅛-in-wide head and a 1/16-in diameter shaft. The drill is positioned against the edge of the inspected pole. Once activated, the drill pushes the bit forward while drilling. The force necessary to push the drill forward and the torque necessary to turn the bit are recorded alongside the current extension of the bit. Decreases in pushing force and/or torque indicate low strength wood or even voids.

Figure 3 shows an idealized cross section of a pole with an overlay of a resistance drill output. On the left side of the figure is good wood characterized by visible distinct peaks corresponding to annual rings. On the right side, in the red shaded area is decayed wood. In the decayed wood, both the torque and the pushing force are very low when compared to the good wood. Near the center of the figure, shaded in yellow, is a suspect area. The height and distinctiveness of the peaks are both decreased, though still visible.

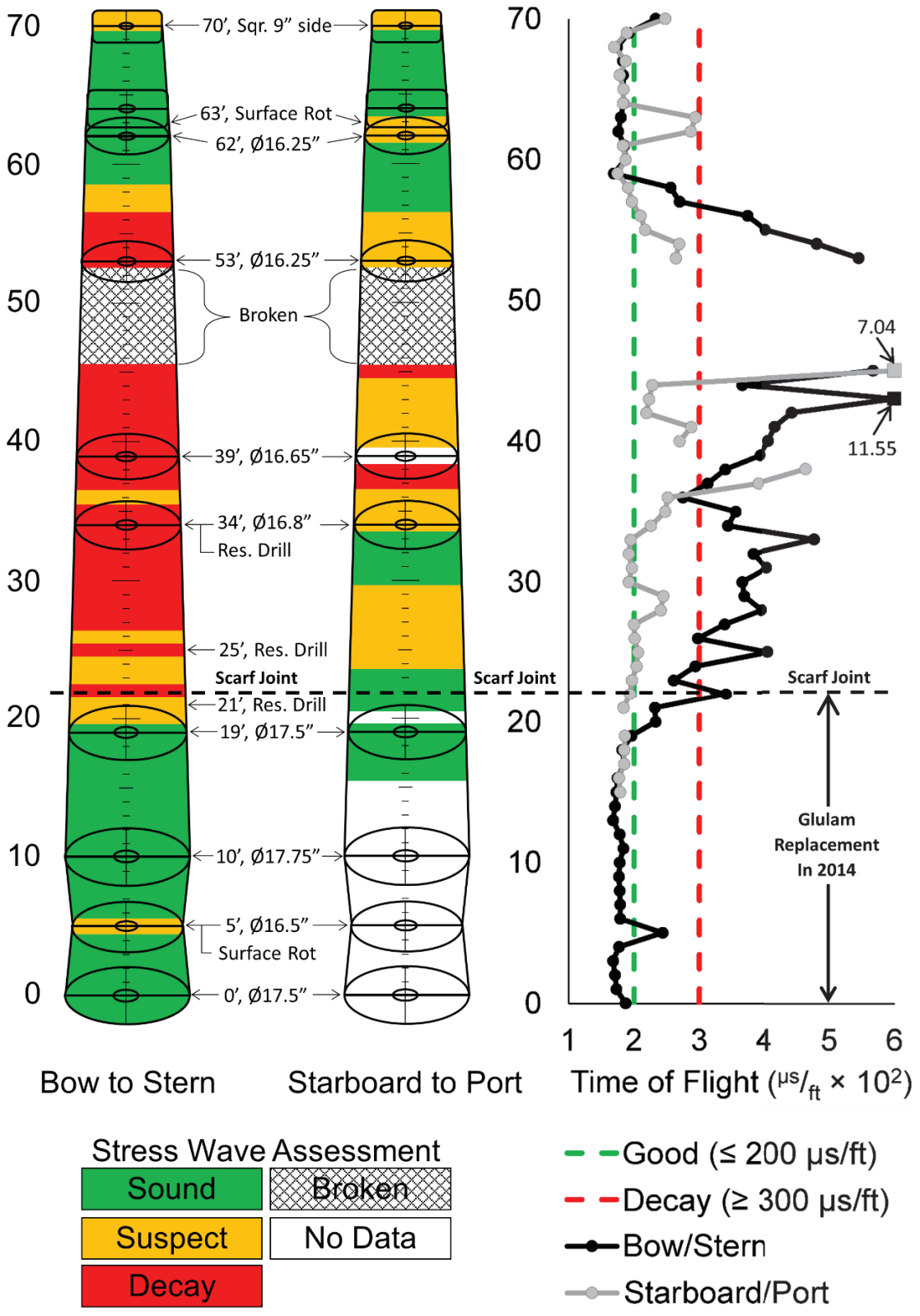

Figure 2. Assessment of mast condition from SWTT. The images on the left show mast condition as indicated by SWTT for the directions of Bow to Stern and Starboard to Port. Time of flight values are given in the chart on the right. Values between 200 and 300 μs/ft are assumed to be suspect.

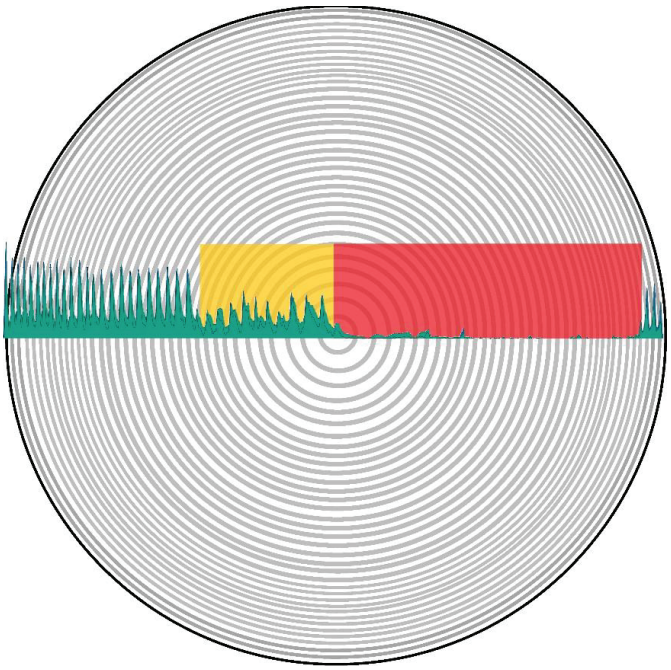

Figure 3. Idealized pole cross section with resistance drill torque and pushing force overlay. Good wood is visible on the left side with tall, distinct peaks corresponding to annual rings. Decayed wood is shaded in red and has no distinct peaks. Suspect wood is shaded in yellow and has visible peaks which are lower in magnitude and less distinct than good wood.

Coast Guard and FPL personnel performed resistance drilling of the mast independently. The Coast Guard took resistance drill measurements every two feet starting at the deck height along the mast and continuing until just below the cross bar. FPL took resistance drill measurements at three locations along the mast: 21-ft, 25-ft, and 34-ft. The FPL measurements at 21-ft were compared to the Coast Guard measurements at 20-ft. Both showed areas of rot starting at or about 1.5-in from the surface which extended to approximately 6-in below the surface. The comparison showed good agreement between both organizations. Variations were attributed to differences in drilling locations and difference in setting for the tool used. **Figure 4a** shows Coast Guard measurements at 20-ft; **Figure 4b** shows FPL measurements at 21-ft.

The resistance drilling results were then compared to the time of flight (ToF) measurements. **Figures 5a** and **5b** shows an idealized cross section of the mast with areas of decay and suspect wood shaded in red and yellow, respectively. Under each image is the height of the measurement, the diameter of the mast at that location, and the ToF along the Bow / sterN (BN) axis and the Starboard / Port (SP) axis. Note that the height values listed are the distance from the base of the mast. The Coast Guard measured height as the distance from the deck. As a result, the resistance drilling heights shown in this report have values 10-ft higher than those in the Coast Guard. The conversion here is for consistency among the report figures. It is apparent that a region of decayed wood is present most of the mast height from the center of the mast to the edge of the mast facing the bow of the ship. Most of the bending strength of a round member comes from the outer shell. As height increases, the decay extends closer to the outer shell of the

mast. There are several areas of suspect wood along the SP axis of the mast, but degradation along the SP axis is noticeably lower than along the BN axis.

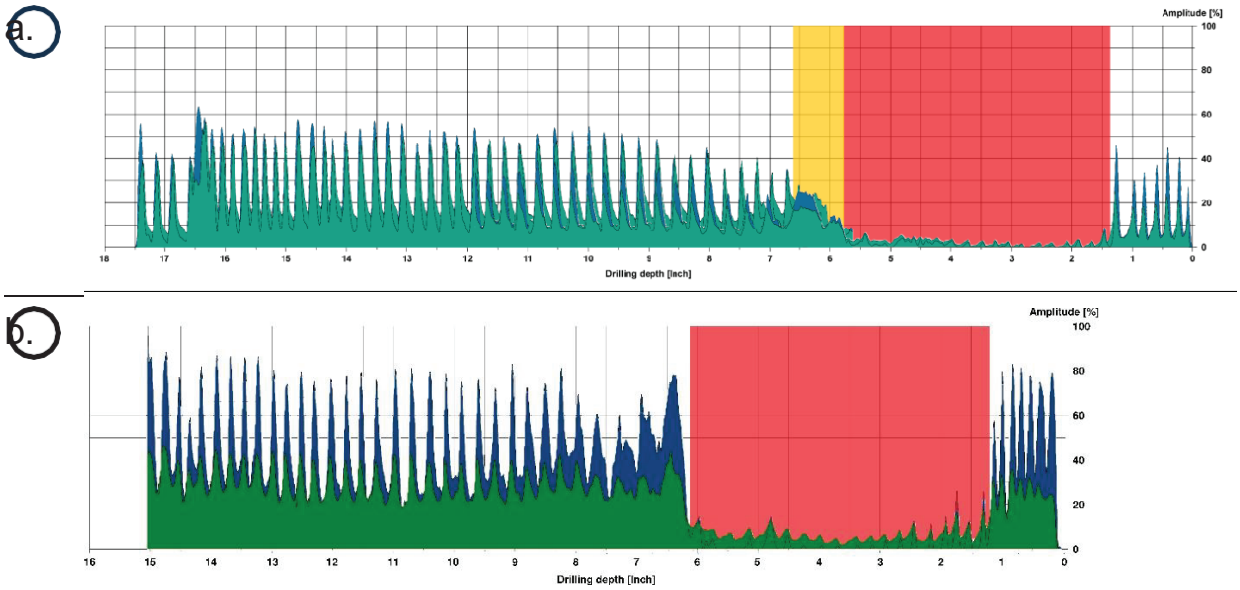

Figure 4. Comparison of Coast Guard and Forest Products Laboratory (FPL) measurements. **A)** Coast Guard measurements at 20-ft height of the mast. **B)** FPL measurements at 21-ft height. Both show decay starting at or above 1.5-in from the front of the mast and extending radially to approximately 6-in.

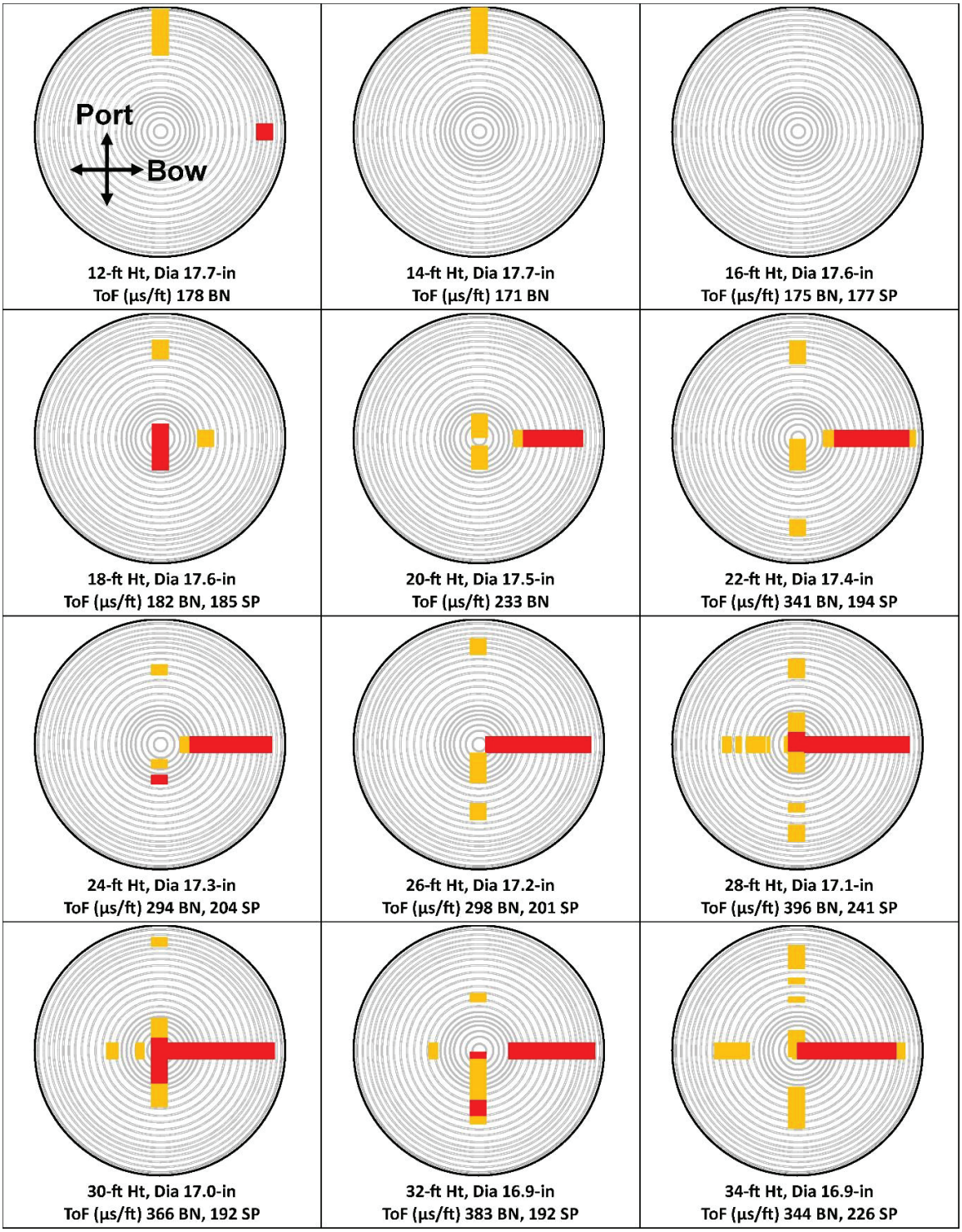

Figure 5a. Resistance drilling results from Coast Guard from 12 to 34-ft mast height. Decayed and suspect wood are indicated by red and yellow shading, respectively. Mast diameter, time of flight (ToF) across the Bow/sterN axis (BN) and across the Starboard/Port (SP) axis are given at each height.

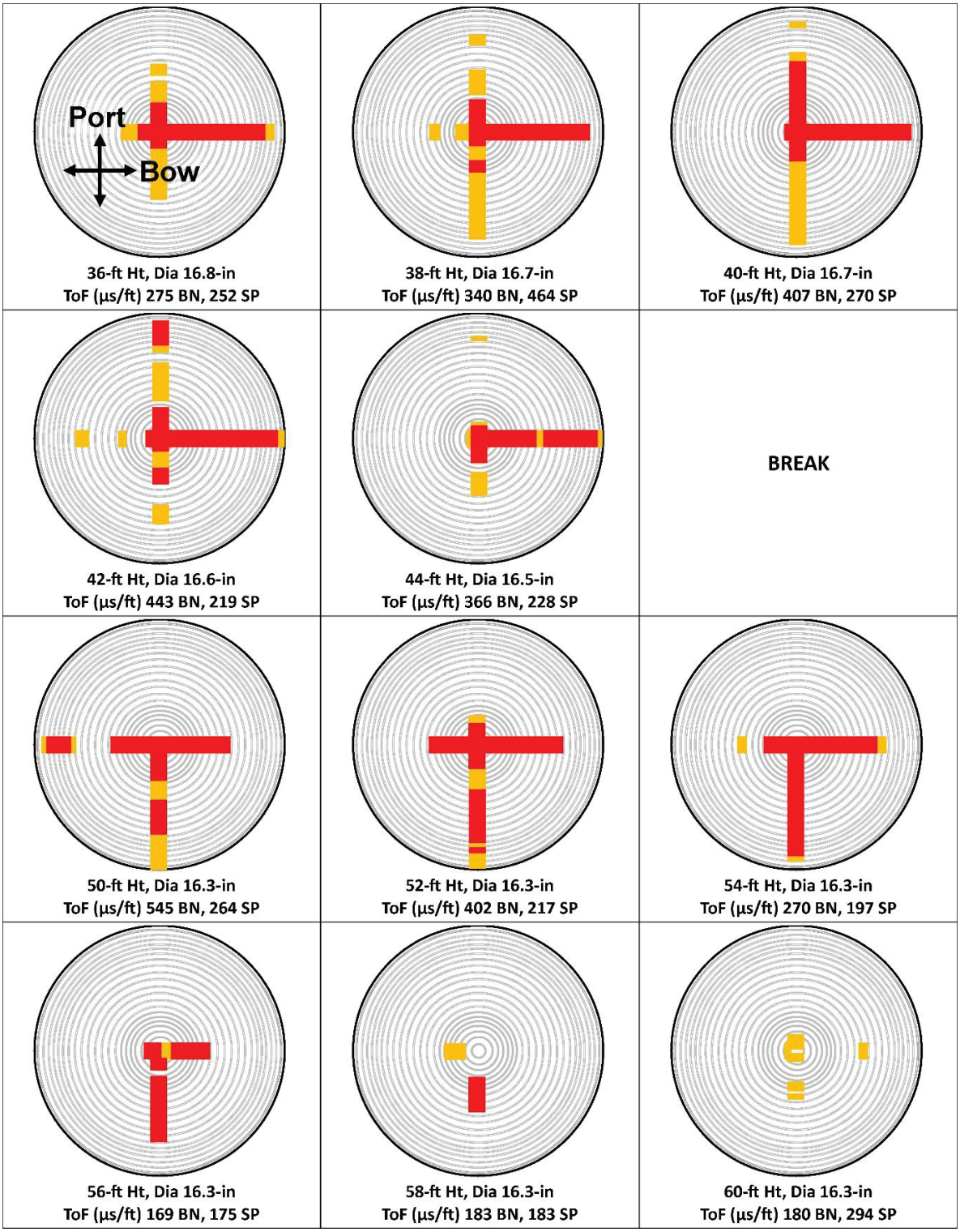

Figure 5b. Resistance drilling results from Coast Guard from 36 to 60-ft mast height. The mast is broken between 44 and 50-ft. Decayed and suspect wood are indicated by red and yellow shading, respectively. Mast diameter, time of flight (ToF) across the Bow/sterN axis (BN) and across the Starboard/Port (SP) axis are given at each height.

Fungal Identification

Brown-rot decayed wood was visually observed in the sections of mast brought to FPL. The presence of a yellow, porous fungus was visually seen on samples of decayed mast. Figure 6 details the 6 sections of decayed wood. Each section of Figure 6 is a result of different sections of decayed mast: A corresponds to breaking point 47-48, B corresponds to the upper breaking point, C corresponds to breaking point 36, D corresponds to breaking point 28, E and F corresponds to breaking point 43 and show active fungal mycelia. The initial examination of the unknown polypore, which caused extensive brown-rot decay of the mast, had a citric yellow pore surface containing small pores. From this examination, it was hypothesized that the unknown polypore could be *Auriporia* (encrusted cystidia), *Laetiporus* (no clamps), *Wolfiporia* (no clamps), *Anomoporia* (monomitic with no skeletal hyphae), or *Antrodia*. Further examination showed dimitic, generative hyphae with multiple clamps and unbranching, thick-walled skeletal hyphae. *Auriporia* typically has encrusted cystidia (sterile cells viewed under the microscope) however, none were found from the unknown polypore. It was determined that the unknown polypore belonged to the genus *Antrodia* and likely is either *Antrodia xantha*, synonymous to *Daedalea xantha*, (Fr.) A. Roy & A.B. De or *Antrodia alpina* (Litsch.) Gilb. & Ryvarden. The Ryvaden and Gilbertson key to North American polypores lists the definitive character between the two as number of pores per millimeter, with 2-4 for *Antrodia alpina* and 5-7 for *Antrodia xantha*. The unknown specimen has frequent instances of 5+ pores/mm, and comparing it to herbarium specimens, the larger pores on *Antrodia alpina* herbarium specimens (2 available and examined) are obvious, with frequent instances of 2 pores/mm. In contrast, herbarium specimens of *Antrodia xantha* examined had frequent instance of 5+ pores/mm, the same range as the unknown specimen. With this information, it is highly likely the unknown polypore is *Antrodia xantha*.

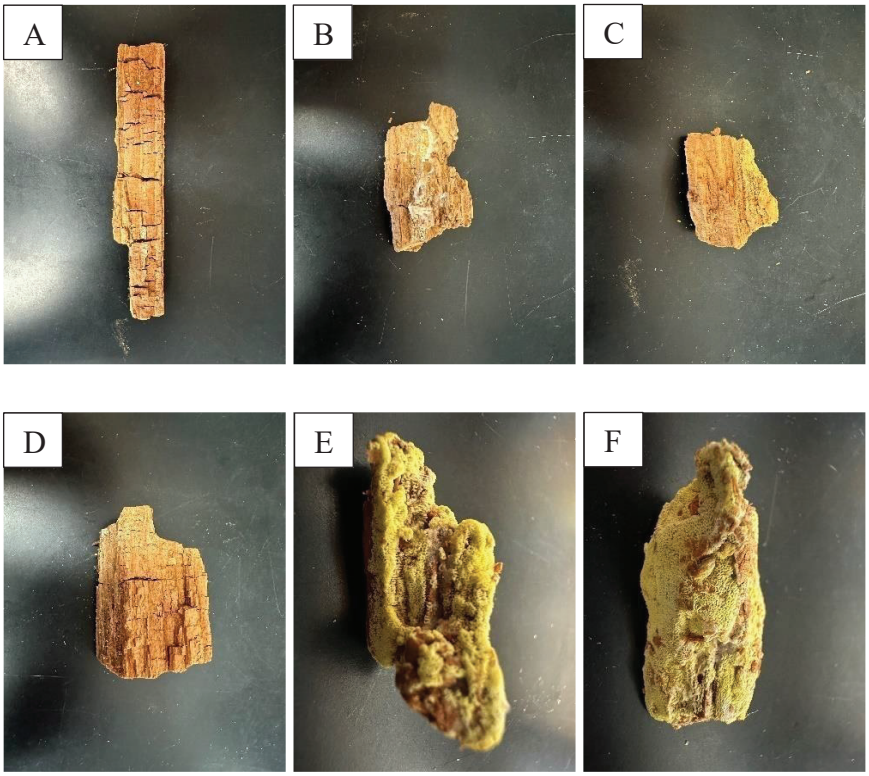

Figure 6. Sections of Douglas-fir decayed mast showing brown-rot and yellow fungal mycelia. A) breaking point 47-48; B) upper breaking point; C) breaking point 36; D) breaking point 28; E-F) breaking point 43.

Remarks on the Effects of Deterioration on Wood Strength

FPL is frequently asked for assistance on the condition of wood and wood products in historic artifacts and structures. We have produced a series of publications on the topic (Ross et al. 2017; White and Ross 2014). It cannot be overemphasized that deterioration in wood resulting from fungal attack results in a significant reduction in strength properties. The following provides a summary of foundation research on this topic.

Toughness (Impact Bending)

Toughness (the ability of a wood member to withstand shock loading) is generally considered to be the strength property most affected in early stages of decay. Research dating to 1954 indicates that a loss of only 1% in weight corresponds to a toughness loss of up to 50%.

Static Bending Properties

Research dating to the 1930s has been conducted on modulus of elasticity, modulus of rupture, and work-to-maximum-load of wood exposed to decay in a bending mode.
Reported results indicated a significant loss in modulus of rupture (strength) after wood had been exposed to decay fungi.

Other Strength Properties

Research has shown that compression strength (perpendicular and parallel to the grain), tension parallel to the grain, shear parallel to the grain, and tangential hardness are also impacted significantly by deterioration caused by decay fungi.

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1. Post Casualty Material Analysis.

1.1. Post-casualty inspections included an initial inspection on October 19, 2023, a visual and hammer tapping inspection on October 20, 2023, a check inspection on October 21, 2023, resistance drill measurements on November 3, 2023, a comprehensive field inspection, with stress wave scanning by United States Forest Service (USFS), Forest Products Lab (FPL) on December 19, 2023, and an examination of standing and running rigging on February 7, 2024.

1.2. The initial evaluation took place aboard *Grace Bailey* on October 19, 2023, at her berth in Rockland, ME. The assessment was completed by members of the Coast Guard Headquarters Traveling Inspection staff and Marine Safety Detachment Belfast.

1.3. Visual inspection revealed extensive internal rotted conditions at the break point of the mainmast. However, the initial evaluation did not reveal any external signs of deterioration that would have prompted an enhanced evaluation had the inspection been part of an annual Coast Guard inspection. The mast surfaces were found smooth, well lubricated with slush, showed no obvious signs of discoloration (lightening or darkening), or any significant mechanical wear.

Figure 1 – Grace Bailey mainmast, October 19, 2023

1.4. On October 20, 2023, *Grace Bailey* shifted to North End Shipyard, Rockland, ME, where the masts were unstepped from the vessel. The mainmast was transported to a covered storage facility in Rockport, ME, where a visual examination was conducted.

Figure 2 – Unstepping and transport of mainmast to cold storage, October 20, 2023.

1.5. The exterior of the mainmast revealed no obvious external signs that would indicate rotted internal conditions. The mast was well coated with slush, smooth, and not discolored (lightening or darkening). Expected wear points in the vicinity of gaff jaw riding locations was noted. The installation of the trees was by way of compression around the mast, with no hardware penetrations into the mast (Figure 3).

1.6. Growth rings well below six rings per inch, with some approaching ¼ inch (Figure 4) were noted. Internal material presented with cubicle fracturing (Figure 5).

1.7. Brash fracturing across growth rings, indicative of advanced decay, was observed across the entire mast cross section (Figure 5).

Figure 3 - Upper mainmast/trees.

1.8. Hammer tapping of the entire length and circumference of the mainmast was conducted. This assessment identified suspect wood at 25 feet, 34 feet and 39 feet above the step. Probing and excavation at 25 feet and 34 feet revealed extensive rot just below the mast surface, with sound wood on the exterior limited to less than one inch. Probing at 39 feet was not conducted, as the hammer penetrated the mast during sounding, revealing severe rotted conditions masked by less than 1/8 inch of seemingly sound exterior wood.

Figure 4 – Deep check present at breakpoint depicting wide growth rings, inadequate penetration of slush, and remnants of mycelial matting.

1.9. Similar findings were observed during visual examination and hammer tapping of the foremast. Probing and excavation of the foremast was not conducted.

1.10. On October 21, 2023, 49 checks were measured and documented. The checks were almost entirely restricted to the forward half of the mast, equally distributed between the port and starboard side.

Figure 5 – Photos depicting brown rot deay at the breakpoint and various locations along lower portion of the broken mainmast.

1.11. Most checks were of nominal width and filled with slush. Being filled with slush concealed their presence and resulted in a more uniform and solid mast exterior appearance than truly existed.

1.12. The oil/wax material was excavated, allowing for measurement and documentation of depth. While most checks were of nominal depth, 13 penetrated into the pith and presented with soft internal wood indicative of rotted conditions.

Figure 6 – Rotted internals concealed by 1/8" thick mast shell.

1.13. On November 3, 2023, the investigation team conducted resistance drill measurements on the mainmast. Resistance micro-drilling measures the relative resistance (torque) of the material. It shows density changes along the drill path that can reveal decay and voids. Measurements were taken across the port to starboard axis, starboard to port axis, bow to stern axis and stern to bow axis at two-foot intervals along the mast, beginning 2-feet above the mast table (12-feet above the base).

1.14. On December 19, 2023, USFS FPL conducted an on-site assessment of the *Grace Bailey* mainmast. Their Condition Assessment Report, detailing methods and findings is enclosed.

1.15. Stress wave scanning measures the time-of-flight (ToF) of stress waves through wood, with ToF values indicating the material condition: less than or equal to 200 µs/ft for sound wood, 200-300 µs/ft for suspect wood, and above 300 µs/ft for decayed wood.

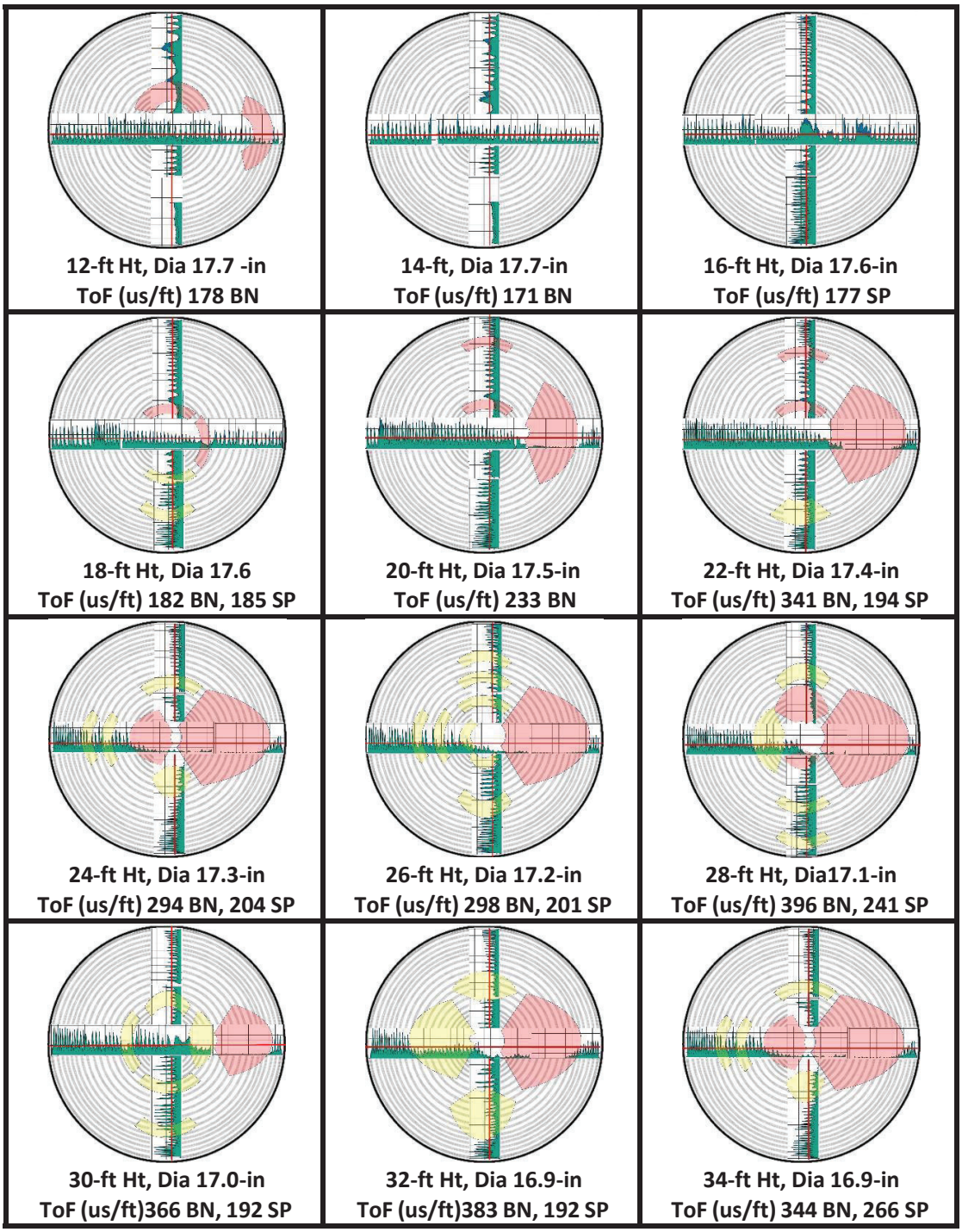


Figure 7 – Resistance drilling results from 12 to 34 ft mast height. Decayed and suspect wood are indicated by red and yellow shading respectively. Mast diameter, time of flight (Tof) across the bow/stern axis (BN) and across starboard/port axis (SP) are given at each height.

1.16. ToF values indicated severe decay, throughout the length of the mast. Severe decay was identified between 26 ft and 56 ft above the mast base in the bow to stern axis. Suspect wood was found along the bow to stern axis from 20 to 26 ft and 56 to 58 ft above the mast base. Along the starboard to port axis, suspect wood was found from 24 to 56 ft with decay at 37 to 38 ft, and severe decay at 45 ft.

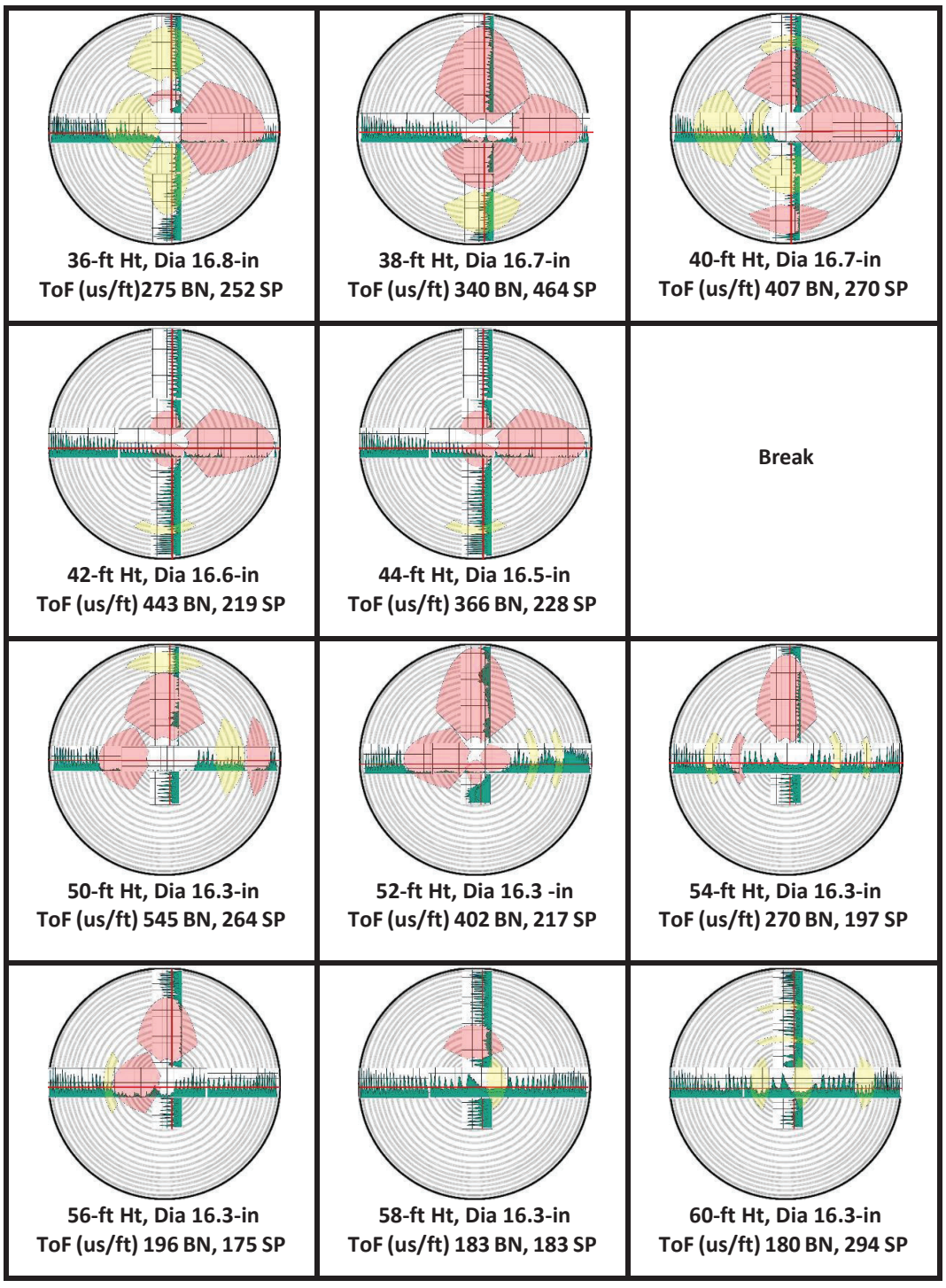
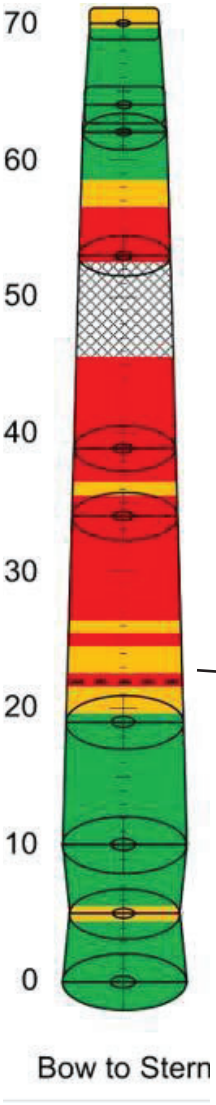


Figure 8 - Resistance drilling results from 36 to 60 ft mast height. Decayed and suspect wood are indicated by red and yellow shading respectively. Mast diameter, time of flight (Tof) across the bow/stern axis (BN) and across starboard/port axis (SP) are given at each height.



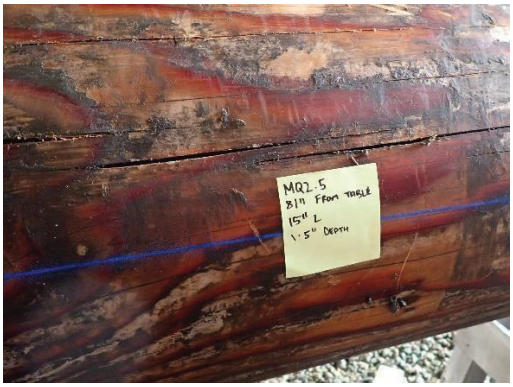


Figure 9 – Check Numbers 2.5 (15" length x 1 ½" depth) and 2.6 (15" length x ½" depth). Probing did not reveal soft wood.

Figure 10 – Check Numbers 2.3 (46" length x ½" depth) and and 2.4 (33"length x ½" depth). Probing did not reveal soft wood.

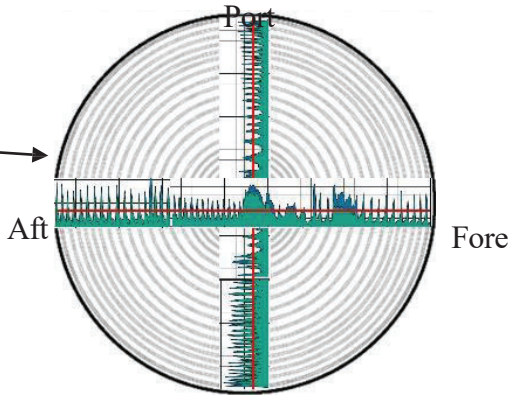


Figure 11 – Idealized cross section showing resistance drill results at 16 feet above the base, no indication of decay or suspect material found.

Figure 12 – Check Numbers 2.1(12" length x 1/2"depth and 2.2 (17" length x 1 ¼" depth). Probing did not reveal soft wood.

1.17. 16 feet above the mast step – ToF and resistance drill did not reveal any suspect wood conditions.

1.18. Visual inspection revealed no anomalies that would prompt further examination. Checks in the vicinity did not present with indications of soft wood.

1.19. Hammer tapping around the circumference revealed no signs of deteriorated conditions.

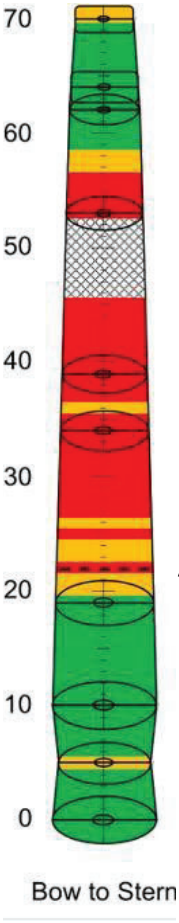


Figure 13 – Check Number 2.9(35" length x ½" depth). Probing did not reveal soft wood

Figure 14 – Check Number 2.10 (46" length x ½" depth). Probing did not reveal soft wood.

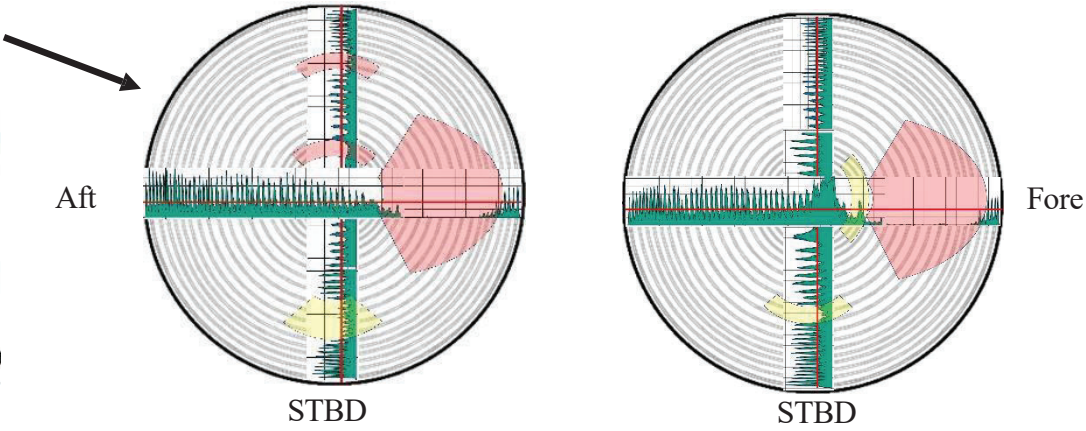


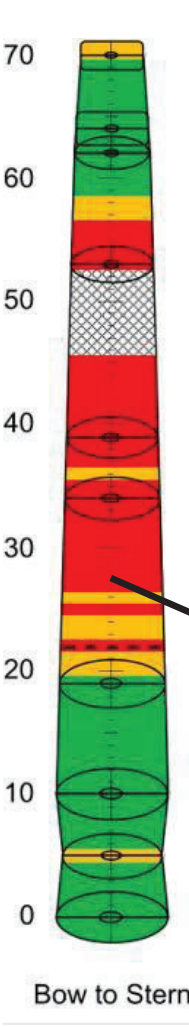
Figure 15 – Idealized cross section showing resistance drill results at 22 feet above the base. Severe decay found along fore/aft axis beginning ~1" inside fore external surface and extending to pith. Small pockets of suspect material and decay found on port/stbd axis

Figure 16 – Idealized cross section showing resistance drill results at 24 feet above the base. Severe decay found along fore/aft axis beginning ~1" inside fore external surface and extending beyond pith. Small pockets of suspect material found along both axes.

1.20. 22 and 24 feet above the mast step. ToF and resistance drill show suspect material along the fore/aft axis.

1.21. Visual inspection revealed no anomalies that would prompt further examination. Checks did not present with indications of soft wood.

1.22. Hammer tapping around the circumference revealed no signs of deteriorated conditions.



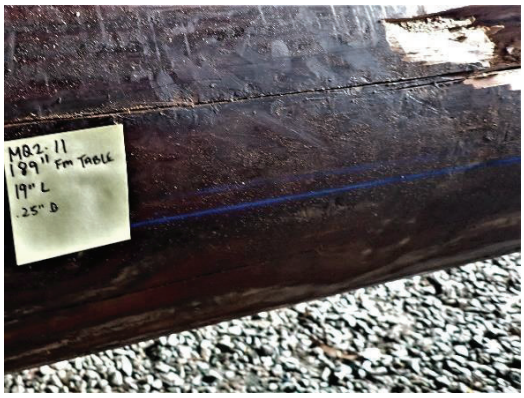


Figure 17 – Check Number 2.11 (19" length x 1/4" depth). Probing did not reveal soft wood.

Figure 18 – Check Number 1.2 (43" length x 1 1/2" depth). Probing did not reveal soft wood.

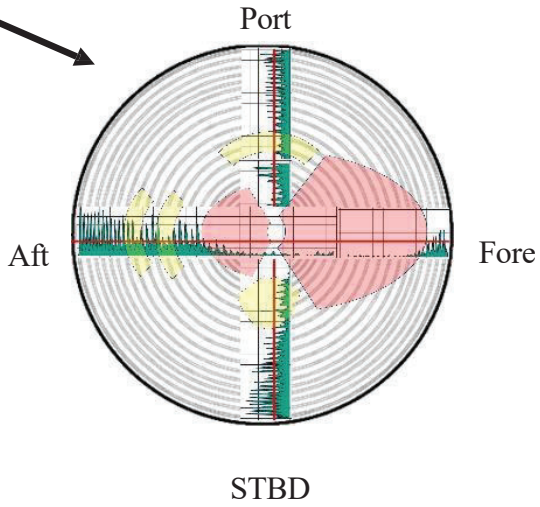
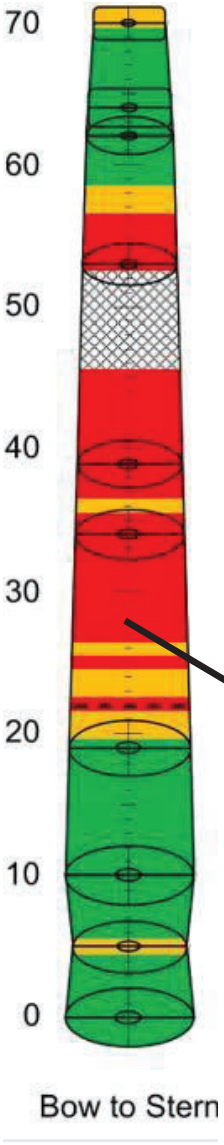


Figure 19 – Idealized cross section showing resistance drill results at 26 feet above the base. Severe decay found along fore/aft axis beginning ~1" inside fore external surface and extending to pith. Small pockets of suspect wood and decay found on both axes.

1.23. 26 feet above the mast step. ToF and resistance drill show suspect and decayed wood along the bow to stern axis and port to starboard axis.

1.24. Visual inspection revealed no anomalies that would prompt further examination. Checks did not present with indications of soft wood.

1.25. Hammer tapping around the circumference revealed clear indications of deteriorated conditions along the forward external surface.



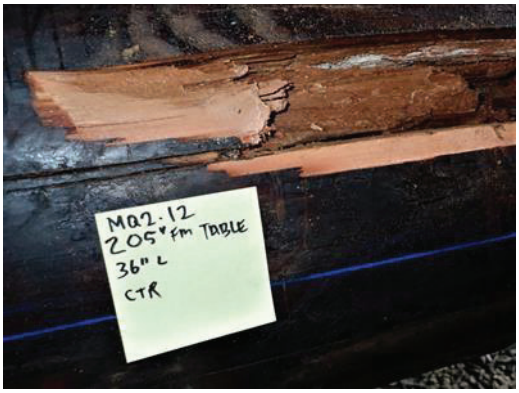


Figure 20 – Check Number 2.12 (36" length). Soft wood apparent with probing. Probe was able to penetrate to the center without resistance.

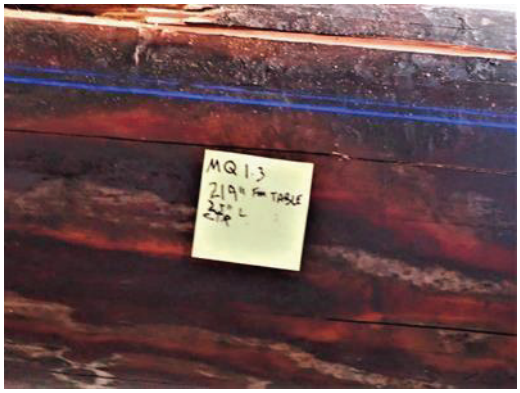


Figure 21 – Check Number 1.3 (23" length). Soft wood apparent with probing. Probe was able to penetrate into center without resistance.

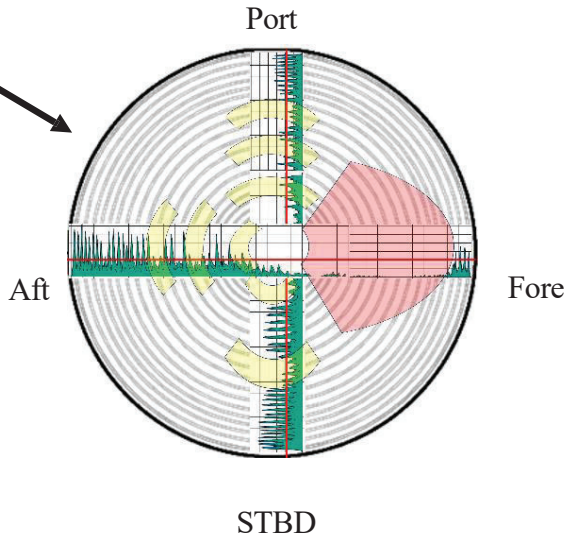
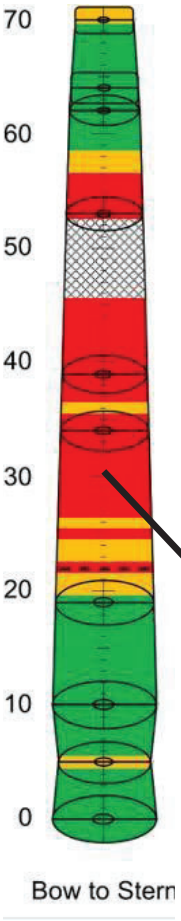


Figure 22 – Idealized cross section showing resistance drill results at 28 feet above the base. Severe decay found along fore/aft axis beginning ~1" inside fore external surface and extending to pith. Small pockets of suspect wood on both axes.

1.26. 28 feet above the mast step. ToF and resistance drill show suspect and decayed wood along the bow to stern axis and port to starboard axis.

1.27. While visual inspection revealed no anomalies that would prompt further examination, checks presented with soft wood.

1.28. Hammer tapping around the circumference revealed clear indications of deteriorated conditions.



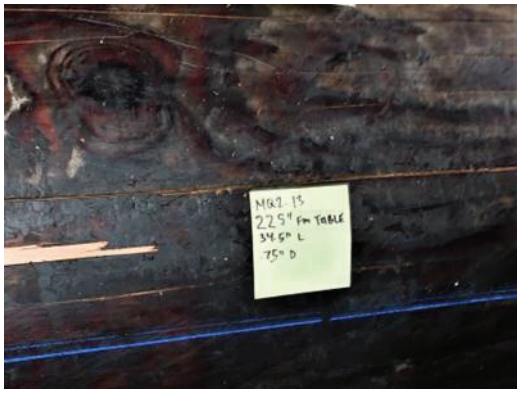


Figure 23 – Check Number 2.13(34 ½" length x ¾" depth). Probing did not reveal soft wood.

Figure 24 – Check Number 1.4 (18" length x ¾" depth). Probing did not reveal soft wood.

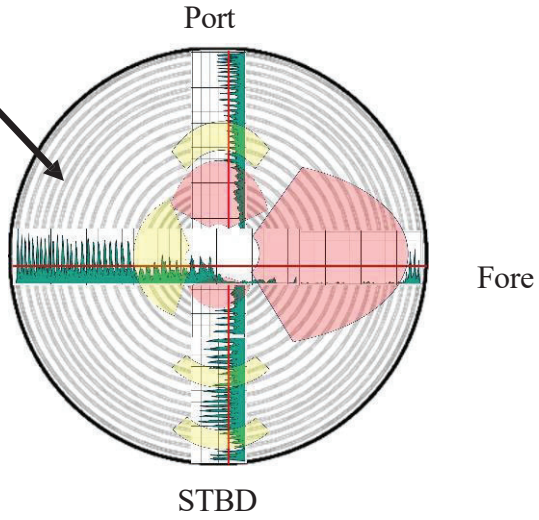


Figure 25 – Idealized cross section showing resistance drill results at 30 feet above the base. Severe decay found along fore/aft axis beginning ~1" inside fore external surface and extending to pith. Small pockets of suspect wood and decay found on both axes.

1.29. 30 feet above the mast step. ToF and resistance drill show suspect and decayed wood along the bow to stern axis and port to starboard axis.

1.30. Visual inspection revealed no anomalies that would prompt further examination. Checks did not present with indications of soft wood.

1.31. Hammer tapping around the circumference revealed no indications of deteriorated conditions.

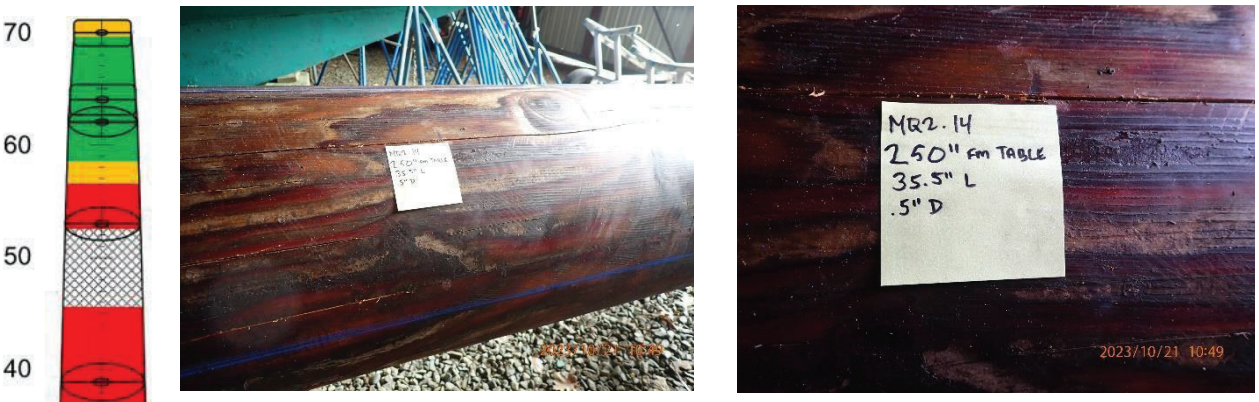


Figure 26 – Check Number 2.14 (35" length x ½" depth). Probing did not reveal soft wood.

Figure 27 – Idealized cross section showing resistance drill results at 32 feet above the base. Severe decay found along fore/aft axis beginning ~1" inside fore external surface and extending to pith. Small pockets of suspect wood and decay found on both axes.

1.32. 32 feet above the mast step. ToF and resistance drill show suspect and decayed wood along the bow to stern axis and port to starboard axis.

1.33. Visual inspection revealed no anomalies that would prompt further examination. Checks did not present with indications of soft wood.

1.34. Hammer tapping around the circumference revealed no indications of deteriorated conditions.

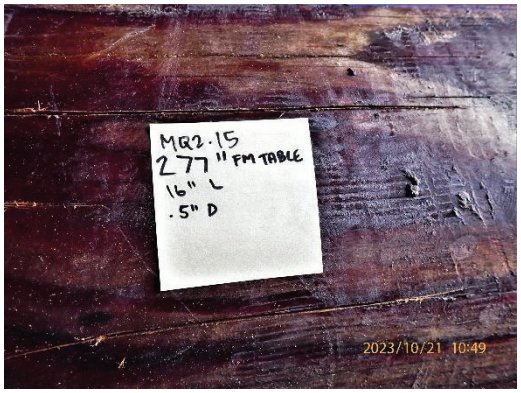


Figure 28 – Check Number 2.15 (16" length x ½" depth). Probing did not reveal soft wood.

Figure 29 – Check Number 1.5 (35" length x 1 ½" depth). Probing did not reveal soft wood.

Figure 30 – Idealized cross section showing resistance drill results at 34 feet above the base. Severe decay found along fore/aft axis beginning ~2" inside fore external surface and extending to pith. Pockets of suspect wood and decay found on both axes.

1.35. At 34 feet above the mast step, ToF and resistance drill show severe decay along the bow to stern axis and suspect wood along the port to starboard axis.

1.36. Visual inspection revealed no anomalies that would prompt further examination. Checks did not present with indications of soft wood.

1.37. Hammer tapping around the circumference revealed no indication of deteriorated material.

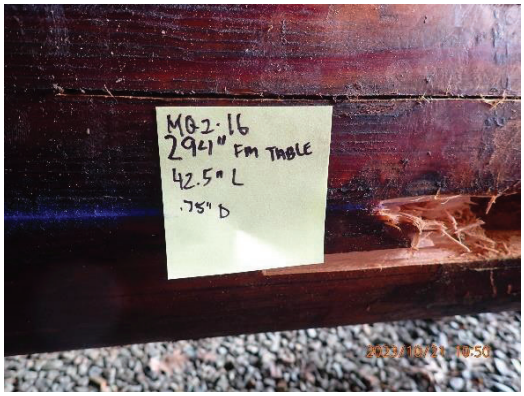


Figure 31 – Check Number 2.16 (42 ½" length x ¾" depth). Probing revelealed soft wood.

Figure 32 – Check Number 1.6 (15" length x 2" depth). Probing revealed soft wood.

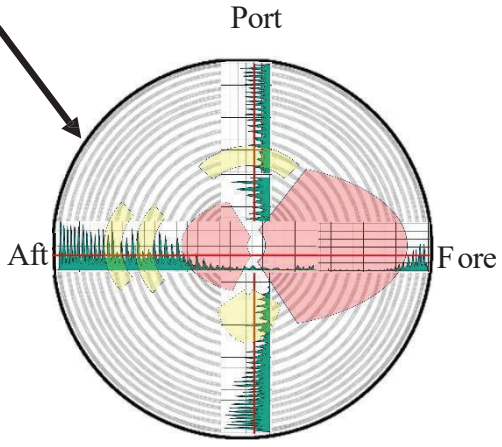


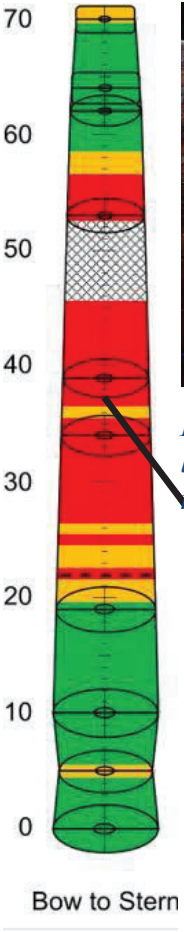
Figure 33 – Idealized cross section showing resistance drill results at 36 feet above the base. Severe decay found along fore/aft axis beginning ~2" inside fore external surface and extending to pith. Small pockets of suspect wood and decay found on both axes.

Figure 34 – Check Number 1.5 (35" length x 1 ½" depth). Probing revelealed soft wood.

1.38. 36 feet above the mast step. ToF and resistance drill show severe decay along the bow to stern axis and suspect wood along the port to starboard axis.

1.39. While visual inspection revealed no anomalies that would prompt further examination, checks presented with soft wood.

1.40. Hammer tapping around the circumference revealed clear indications of deteriorated conditions.



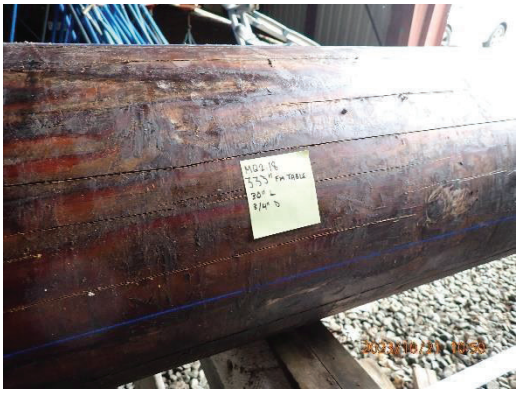


Figure 35 – Check Number 2.18 (30" length x ¾" depth). Probing did not reveal soft wood.

Figure 36 – Check Number 1.7 (44" length). Probing revealed soft wood, penetrating into the center without resistance.

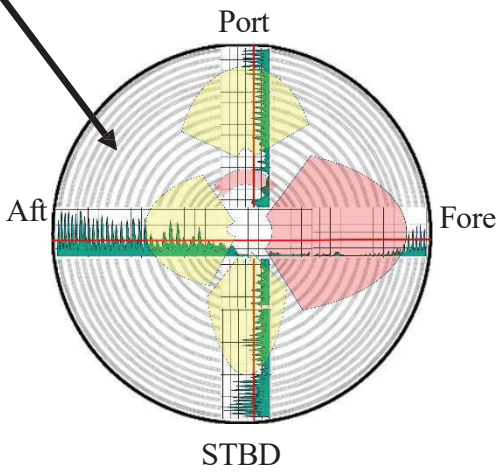


Figure 37 – Idealized cross section showing resistance drill results at 38 feet above the base. Severe decay found along fore/aft axis beginning ~2" inside fore external surface and extending to pith. Pockets of suspect wood and decay found on both axis.

Figure 38 – Check Number 1.8 (44" length). Probing revealed soft wood, penetrating into the center without resistance.

1.41. 38 feet above the mast step. ToF and resistance drill shows severe decay along the bow to stern axis and port to starboard axis.

1.42. While visual inspection revealed no anomalies that would prompt further examination, checks presented with soft wood.

1.43. Hammer tapping around the circumference revealed clear indications of deteriorated conditions.

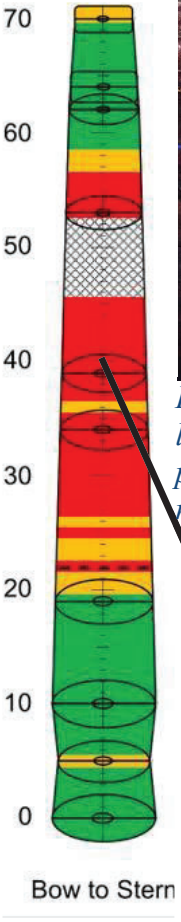


Figure 39 – Check Number 1.9 (35" length). Probing revealed soft wood, penetrating into the center without resistance.

Figure 40 – Check Number 1.10 (18" length) Probing revealed soft wood, penetrating into the center without resistance.

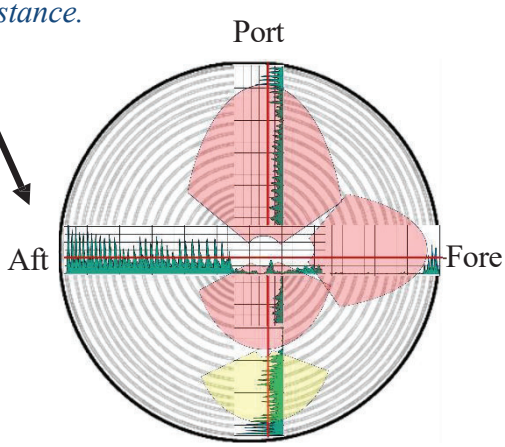


Figure 41 – Idealized cross section showing resistance drill results at 40 feet above the base. Severe decay found along fore/aft axis beginning ~1" inside fore and port external surface and ~4" inside the starboard external surface.

Figure 42 – Check Number 1.10 (18" length) Probing revealed soft wood, penetrating into the center heartwood without resistance.

1.44. 40 feet above the mast step. ToF and resistance drill show severe decay along the bow to stern axis and port to starboard axis.

1.45. While visual inspection revealed no anomalies that would prompt further examination, checks presented with soft wood.

1.46. Hammer tapping around the circumference revealed clear indications of deteriorated conditions.

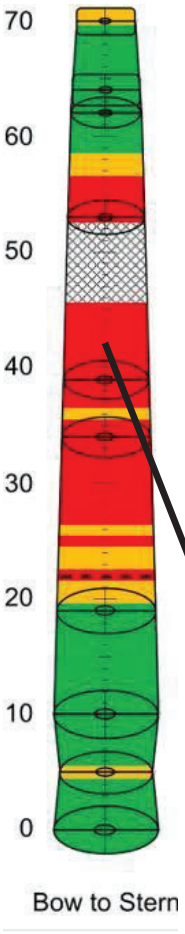


Figure 43 – Check Number 2.23 (27" length). Probing revealed soft wood, penetrating into the center without resistance.

Figure 44 – Check Number 1.12 (51" length). Probing revealed soft wood, penetrating into the center without resistance.

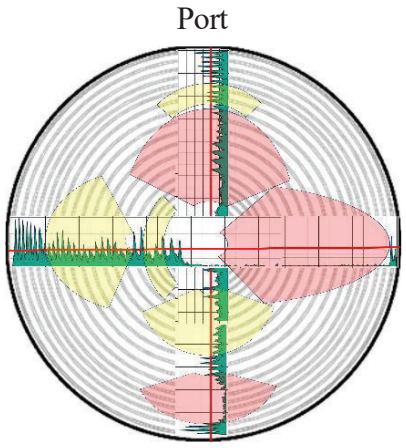


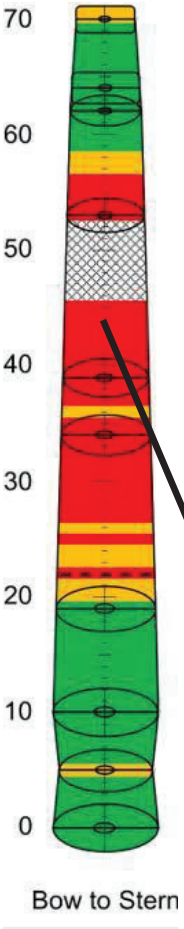
Figure 45 – Idealized cross section showing resistance drill results at 42 feet above the base. Severe decay found along both axes beginning ~1" inside fore and starboard external surface and ~3" inside the port external surface.

Figure 46 – Check Number 1.11 (18" length). Probing revealed soft wood, penetrating into the center without resistance.

1.47. At 42 feet above the mast step, ToF and resistance drill show severe decay along both axes.

1.48. Visual inspection revealed some deflection of exterior surfaces in way of multiple checks. However, it could not be determined if this condition was the result of mechanical damage from the casualty or if the condition would have been visible prior to casualty.

1.49. Hammer tapping around the circumference revealed clear indications of deteriorated conditions. While testing, the inspection hammer penetrated the outer shell, revealing severe rot that had been concealed by ~1/8" of outer shell wood.



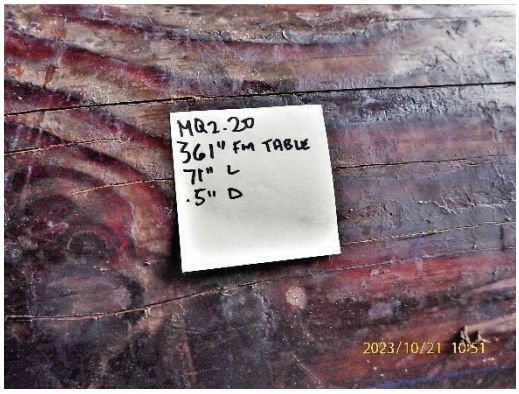


Figure 47 – Check Number 2.20 (71" length x ½" depth). Probing did not reveal soft wood.

Figure 48 – Check Number 2.24 (63" length). Probing revealed soft wood, penetrating into the center without resistance.

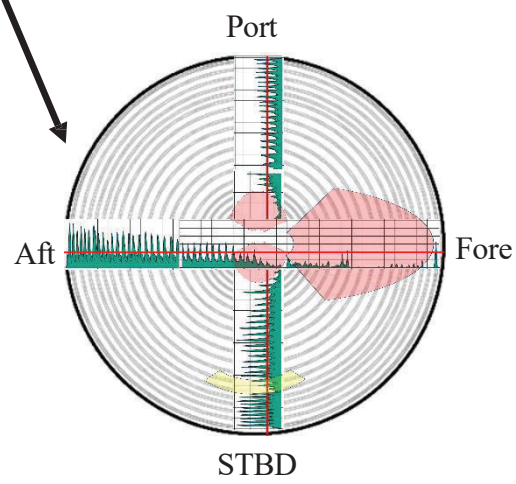


Figure 49 – Idealized cross section showing resistance drill results at 44 feet above the base. Severe decay found along the fore/aft axis beginning ~1" inside the fore external surface and extending beyond the pith.

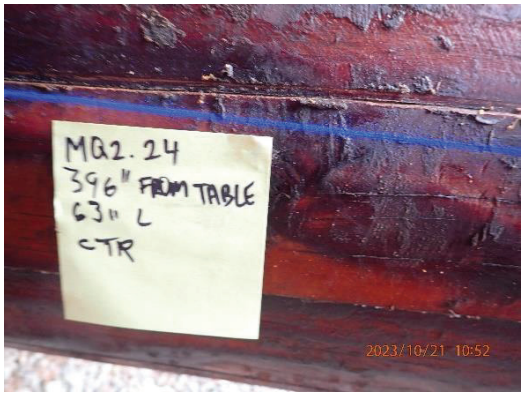


Figure 50 – Check Number 2.24 (63" length). Probing revealed soft wood, penetrating into the center without resistance.

1.50. 44 feet above the mast step. ToF and resistance drill shows suspect and decayed wood along both axes.

1.51. Visual inspection of external surface for comparison to inspection procedures was of limited value as all external surfaces in way of the break point were fractured and deflected.

1.52. Hammer tapping the external surface for comparison to inspection procedures was of limited value.

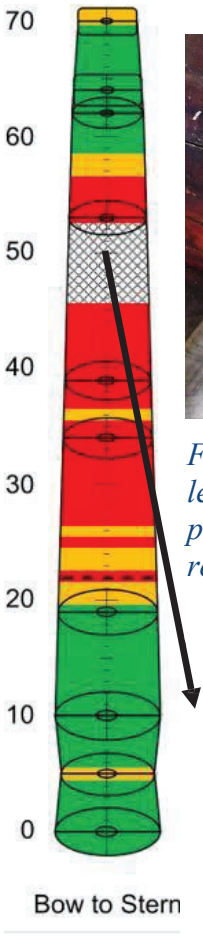


Figure 51 – Check Number 4.2 (66" length). Probing revealed soft wood, penetrating into the center without resistance.

Figure 52 – Check Number 4.3 (57" length) Probing revealed soft wood, penetrating into the center without resistance.

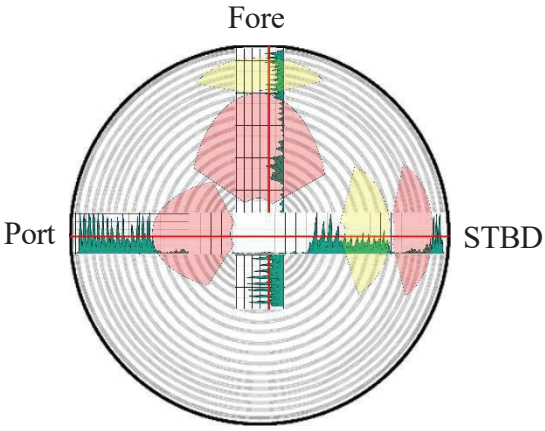


Figure 53 – Idealized cross section showing resistance drill results at 50 feet above the base. Severe decay found along both axes beginning ~1" inside fore and starboard external surface and ~3" inside the port external surface.

Figure 54 – Check Number 1.13 (26" length x 2 ¼" depth). Probing did not reveal soft wood.

1.53. 50 feet above the mast step. ToF and resistance drill show severe decay along the bow to stern axis and suspect wood along the port to starboard axis.

1.54. Visual inspection of external surface for comparison to inspection procedures was of limited value as all external surfaces in way of the break point were fractured and deflected.

1.55. Hammer tapping the external surface for comparison to inspection procedures was of limited value.

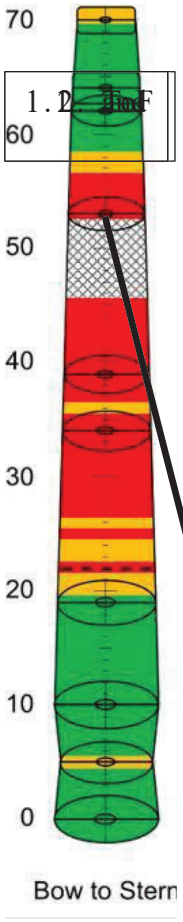


Figure 55 – Check Number 4.3 (57" length) Probing revealed soft wood, penetrating into the center without resistance.

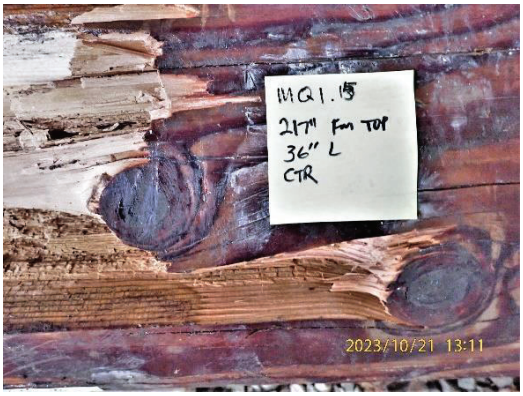


Figure 56 – Check Number 1.15 (36" length). Probing revealed soft wood, penetrating into the center without resistance.

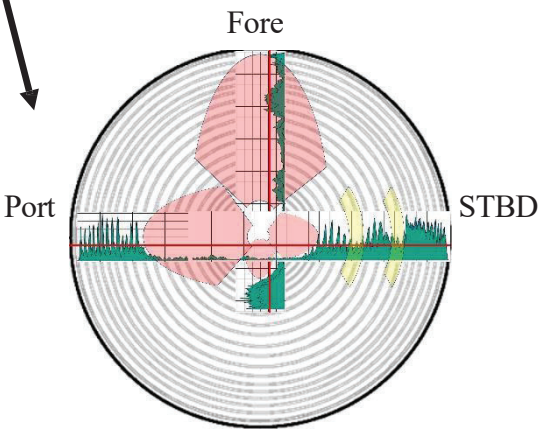


Figure 57 – Idealized cross section showing resistance drill results at 52 feet above the base. Severe decay found along both axes beginning ~1" inside fore external surface and ~3" inside the port external surface.

Figure 58 – Check Number 1.14 (18" length x ½" depth). Probing did not reveal soft wood.

1.56. 52 feet above the mast step. resistance drill show severe decay and suspect wood along both axes.

1.57. Visual inspection of external surface for comparison to inspection procedures was of limited value as all external surfaces in way of the break point were fractured and deflected.

1.58. Hammer tapping the external surface for comparison to inspection procedures was of limited value.

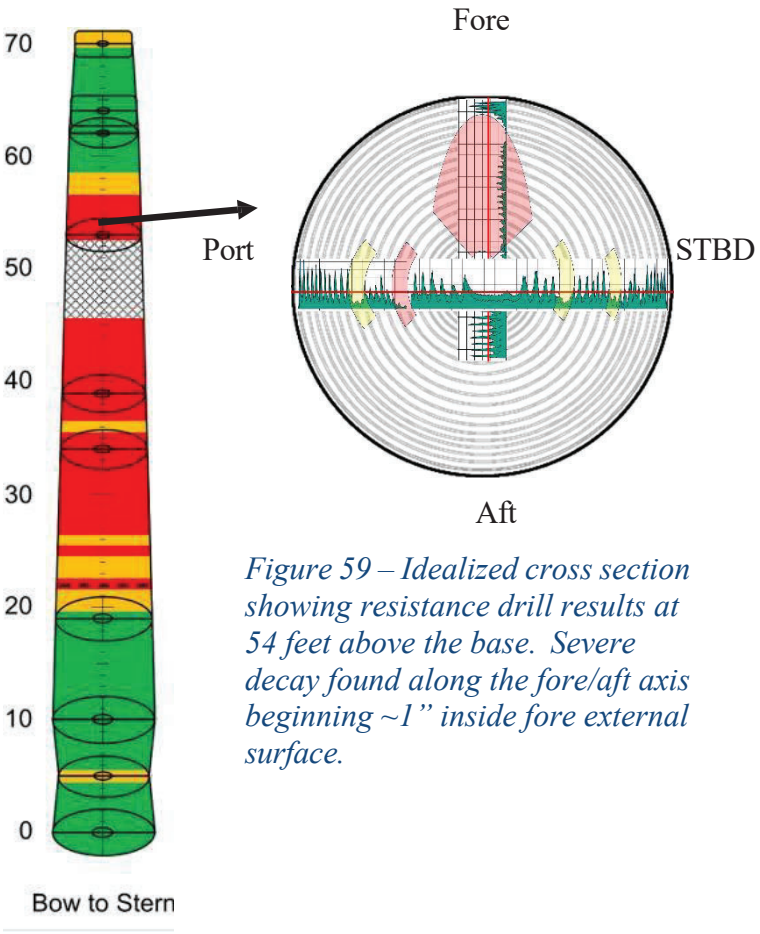


Figure 59 – Idealized cross section showing resistance drill results at 54 feet above the base. Severe decay found along the fore/aft axis beginning ~1" inside fore external surface.

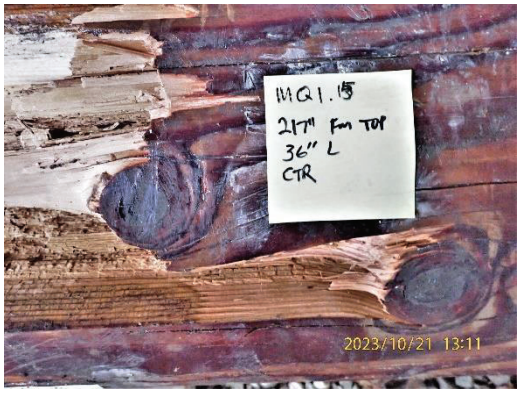
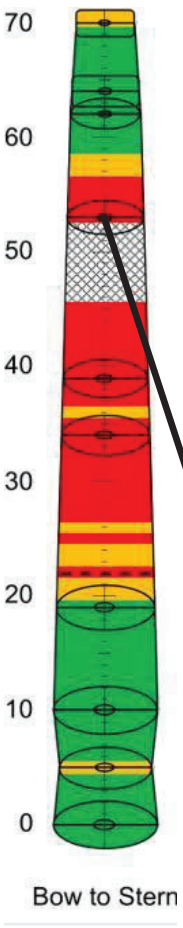


Figure 60 – Check Number 1.15 (36" length). Probing revealed soft wood, penetrating into the center without resistance.

1.59. 54 feet above the mast step. ToF and resistance drill show severe decay along the bow to stern axis and suspect wood along the port to starboard axis.

1.60. While visual inspection revealed no anomalies that would prompt further examination, checks presented with soft wood.

1.61. Hammer tapping around the circumference revealed no signs of deteriorated conditions.



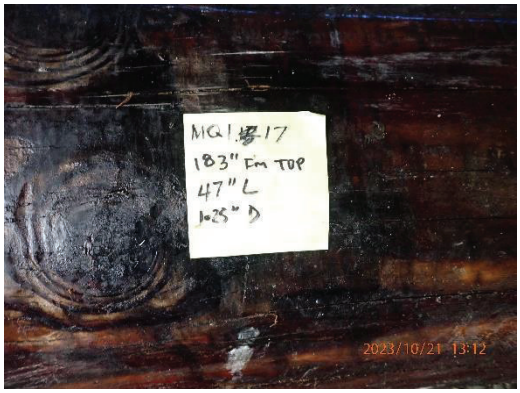


Figure 61 – Check Number 1.17 (47" length x 1 ¼" depth). Probing did not reveal soft wood.

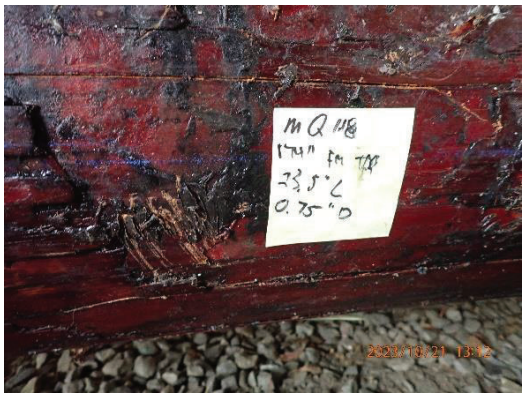


Figure 62 – Check Number 1.18 (23 ½" length x ¾" depth).). Probing did not reveal soft wood.

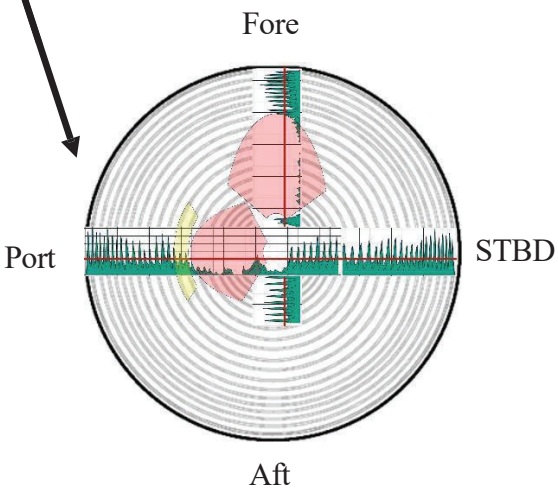


Figure 63 – Idealized cross section showing resistance drill results at 56 feet above the base. Severe decay found along both axes beginning ~2" inside fore external surface and ~6" inside the port external surface.

1.62. 56 feet above the mast step. ToF and resistance drill show severe decay along both axes.

1.63. Visual inspection revealed no anomalies that would prompt further examination. Checks did not present with indications of soft wood.

1.64. Hammer tapping around the circumference revealed no signs of deteriorated conditions.

1.65. Brown-rot decay and porous yellow fungus (Figure 68) were observed at the break point and excavation points. The remnants of white mycelial matting were observed along check surfaces (Figure 69). Through culturing and examination of the resultant specimens, USFS FPL identified the fungus as *Antrodia xantha*.

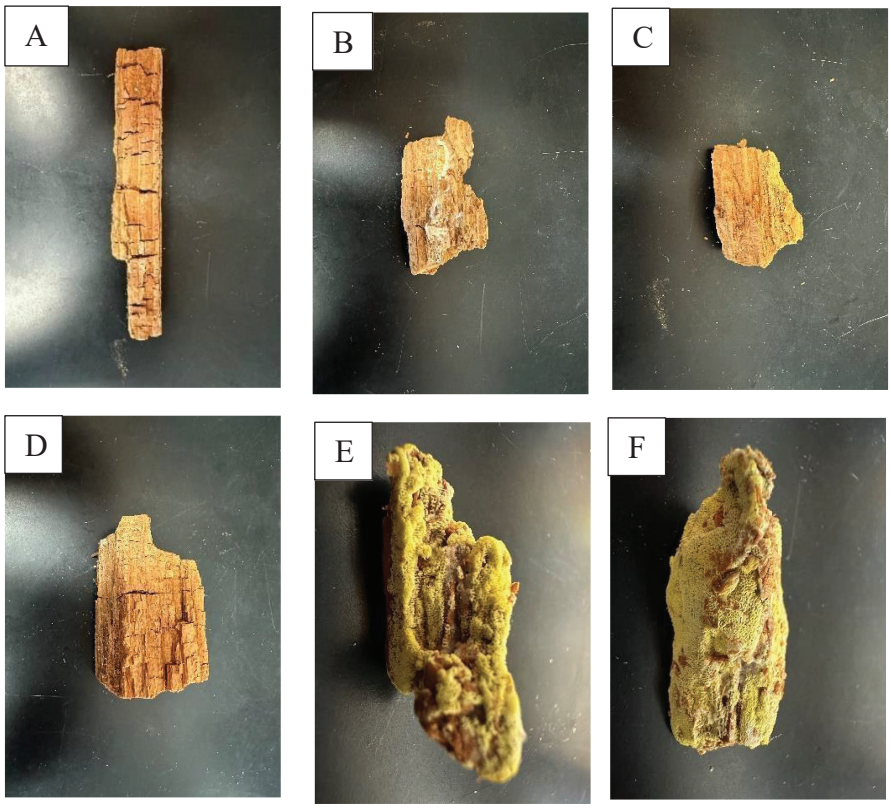


Figure 64 – Sections of decayed mast showing brown-rot and yellow fungal mycelia. A) breaking point 47-48 ft; B) upper breaking point; C) breaking point 36 ft; D) breaking point 28 ft; E-F) breaking point 43 ft.

Figure 65 – White mycelial matting observed along check surfaces

1.66. A study documented in Morrell (1991) sought to identify the prevalence of fungal infection at lumber yards in the Pacific Northwest (PNW). In that study, 27 separate fungal species were isolated from Douglas fir poles over the course of a three year period. In total, 10,124 sample cores were taken from Douglas fir stock located at four separate PNW air

seasoning yards. Of those cores, 7,860 (77%) were found to have been colonized by decay fungus. 210 (2%) had been colonized by *Antrodia xantha*.

1.67. A study documented in Sexton, Corden, and Morrell (1992) sought to quantify strength losses in wood infected with various decay fungi. In that study, *Antrodia xantha* was identified as an aggressive wood decayer and was amongst the most severe wood decayers in the study.

1.68. A study documented in Schmidt and Moreth (1996) provides insight on average mycelial growth rates for various poria type fungus, including *Antrodia xantha*. The growth rate of *Antrodia xantha* was found to be 3.7 mm/day at 71.6°F, 4.5 mm/day at 77°F, 5.1 mm/day at 82.4°F, 5.5 mm/day at 87.8°F, and 4.4 mm/day at 93.2°F.

1.69. Toughness (the ability of a wood member to withstand shock loading) is generally considered to be a strength property most affected in the early stages of decay. Research dating to 1954 indicates that a loss of only 1% in weight corresponds to a toughness loss of up to 50%.

1.70. Research dating to the 1930s has been conducted on modulus of elasticity, modulus of rupture, and work-to-maximum-load of wood exposed to decay in bending mode. Reported results indicate a significant loss in modulus of rupture (strength) after wood had been exposed to decay fungi.

1.71. Research has shown that compression strength (perpendicular and parallel to the grain), tension parallel to the grain, shear parallel to the grain, and tangential hardness are also impacted significantly by deterioration caused by fungi.

1.72. On February 27, 2024, an assessment of standing and running rigging was completed. In stark contrast to other recent dismasting investigations, the *Grace Bailey* rigging was found entirely intact, with no signs of failure or deterioration.