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The Protection of the  
Underwater Cultural Heritage

## APPENDIX C

Author Christopher J. Underwood

# Introduction to Metal Shipbuilding Technology



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# APPENDIX C

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# APPENDIX C

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## Introduction to Metal Shipbuilding Technology

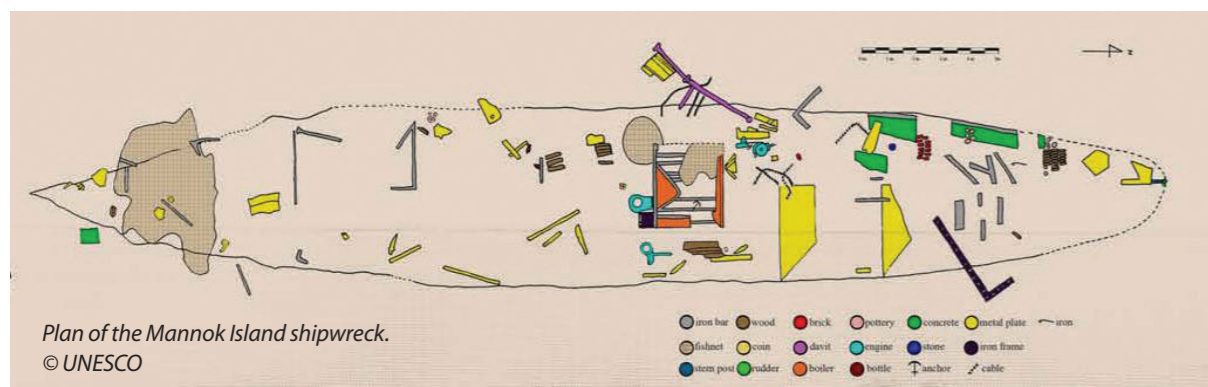
### Core Knowledge of the Appendix

On completion of the Introduction to Metal Shipbuilding Technology appendix students will:

- Understand the various factors that influence the design of vessels
- Understand how vessels gradually evolved from wood to metal and from sail to steam in different geographic regions
- Have knowledge of the terminology and function of the main structural components of metal ships
- Have knowledge of the terminology and function of the propulsion system of a metal steamship
- Have knowledge of the terminology and function of deck fixtures and fittings
- Understand how nautical terms are a technical language
- Understand how a shipwreck can be identified by the study of its structure
- Understand how a metal shipwreck's structural integrity will deteriorate at varying rates according to the site's environmental conditions
- Have knowledge of where and in what condition, structural components, fixtures and fittings are commonly found on wreck sites

### Introduction to the Appendix

This appendix provides students with sufficient knowledge of metal shipbuilding technology to enable an assessment of the Mannok shipwreck site (see Additional Information 1) and is in addition to Unit 14: Asian Shipbuilding Technology.



This appendix assumes that students have a low level of prior knowledge of the subject and is therefore aimed at providing an introduction to metal ship construction, propulsion, fixtures and fittings.

Although some components referred to, such as the lower structural features, (keel, keelson, floors and the propeller) are not currently visible on the Mannok wreck site they are fundamental parts of a metal steam powered vessel and so are included.

### 1 Metal Ship Construction

For the purposes of the Foundation Course, students require the knowledge to:

- Identify, interpret and assess the condition of the main structural components of the Mannok shipwreck including parts of the propulsion system and other fixtures and fittings
- Recognize and interpret the cultural objects that form part of the site, plus other material that although forms part of the wreck site, is not an original part of the site. (See Additional Information 2)

To place the content in a cultural heritage/archaeological context, and although Unit 14 has covered these topics, this lecture also reminds students that the same relationships apply to metal shipwrecks:

- How the relationships between factors such as ideology, technology, tradition, economy, use, climate and materials, influence the construction of (metal) vessels
- The importance of studying material cultural remains from different perspectives, including historical, technological and social
- The transition from wooden to metal vessels is not the same in all geographic regions (See Additional Information 3)
- In common with wooden vessels, metal vessels are designed for specific purposes, for example, war and trade and fishing, but within these categories there is a large variety of shape, size and design

#### ADDITIONAL INFORMATION

1 The assessment forms part of the development of a management plan for the wreck site, as well as providing information for the storyboards in Unit 16: *Museology*.

2 Within the wreck site there are numerous objects associated with fishing, including small clusters of rocks roped together or in small nets to form anchors or net weights, larger fish traps, as well as detritus such as bottles, cans, plastics, etc.

3 Transition from wood to metal and from sail to steam. These factors are particularly important for courses in other geographic regions where there might be different traditions.

This is illustrated using the example of copper nails in the Bronze Age wreck Kyrenia and the use of iron fastenings in predominantly wooden constructed European vessels, dating from the fifth century AD. (See Suggested Reading: Milne, G. McKewan. C. and Goodburn, D. (1998). This then evolves into the use of more substantial structural ship components, such as iron knees from the seventeenth century (See Suggested Reading: Goodwin, P. 1997), iron-clad steam powered vessels in the mid-nineteenth century, to the metal steam powered vessels characteristic of the late nineteenth and early twentieth century.



As this appendix is part of the preparation for the fieldwork, it is important that trainers explain and illustrate to what extent components can be expected to survive in a typical wreck site. (See *Additional Information 4*)

 **Suggested Reading**

- Adams, J. 2001. Ships and Boats as Archaeological Source Material. *World Archaeology*, Vol. 32(3). Taylor and Francis Ltd, pp. 292-310.
- Conlin, L. D. 1998. Ship Evolution, Ship 'Ecology' and the 'Masked Value Hypothesis'. *The International Journal of Nautical Archaeology*. No.27, pp. 3-15.
- Delgado, J.P. (ed.). 1997. *Encyclopaedia of Underwater and Maritime Archaeology*. London, British Museum Press.
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ADDITIONAL INFORMATION

**4** Deterioration of wreck material. The survival and rate of change is dependent on a number of factors:

- The length of time underwater
- Dynamic nature of the sinking
- Human impacts to the site, such as salvage and fishing

Combined with the site's specific environmental characteristics, such as:

- Salinity
- Temperature
- Oxygenation
- Light
- Marine growth
- Water movement
- Burial by sediments

NB. This description is aimed at stating that ferrous metal objects will usually be more corroded and, therefore, are less easily recognizable than non-ferrous objects. It is not a detailed explanation of the physical, biological or chemical processes, which are covered in considerable depth in Unit 11: *Finds Handling and Conservation*.

**5** The aim of a nautical architect is to design a vessel that is 'fit for purpose' and to be economical in the use of materials in its construction and conform to regulations.

LEFT: The badly eroded bow section of the Mannok Island shipwreck. © UAD, Thailand

## 2 Description of the Main Structural Features

In relatively simple terms a ship can be considered a box that is strengthened by numerous parts that join, brace or provide support. The strength of the box is dependent on each of these individual components, noting that some parts are more important than others in keeping the vessel afloat and is only as strong as its weakest component. (See *Additional Information 5*)



Although the chain locker is below the deck, a capstan, mooring bollard (double bitt), anchor derrick and anchor can all be seen on the foredeck. © Christopher J. Underwood

**Bow:** the forward part of a vessel's hull.

Other ancillary parts of the ship and equipment associated with the bow include: the chain locker, anchors, anchor chain, hawse pipe(s), cargo derrick, capstan(s), windlass, and mooring bitts.

**Forecastle:** is often where the crew's cabins are located and can be defined as the section of the deck that is forward of the foremast (if one is present).

**Stem:** the leading part of the bow. It is joined to the keel and rises to the forecastle.

**Stern:** the rear part of a nineteenth century vessel's hull that includes the stern frame, steering gear, rudder and propeller.

**Stern frame:** consists of the rudder post, body post and connecting arch, with an extension for the connection to the keel.

TOP RIGHT: The bow section of a late nineteenth century vessel's hull. © Christopher J. Underwood

MIDDLE RIGHT: Stern of a nineteenth century vessel showing the stern frame arch and top of the rudder. © Christopher J. Underwood

RIGHT: Stern frame arch and the top part of the rudder on the Mannok Island shipwreck. © UAD, Thailand







From left to right, ship's navigation compass, ship's wheel and telegraph. © Christopher J. Underwood



Ship's bridge. © Christopher J. Underwood

Other parts of the vessel and equipment associated with stern include: the steering gear, propeller, capstan(s), windlass and mooring bits.

**Rudder:** hangs on the stern frame by hinges which are formed by two parts, pintles and gudgeons. The weight of the rudder is normally supported by the lower gudgeon.

**Gudgeons:** attached to the stern frame or can be cast or forged as an integral part of it.

**Pintles:** part of the rudder assembly.

**Middle or midship:** the remaining portion of the hull between the bow and stern sections. Usually a more rectangular box shape containing components such as the cargo holds, fuel and water tanks, boilers, engine room. On the upper deck are located the cargo hatches, cargo winches, bridge and smaller fittings, such as scuppers (fittings that allow excess water to run off the decks) that often survive on shipwrecks.

**Keel:** is located along the exterior centre line of a vessel's hull between the stem and stern frame. The keel can have a flat profile known as a flat keel plate or it can be a distinct rectangular shaped section, known as a bar keel.



**Keelson:** the corresponding reinforcement plate or beam that is located down the interior centreline of the vessel between the stem and stern. The keelson is fixed to the transverse structural components, such as floors.

**Floor(s):** vertical plates that extend laterally across the vessel from the keelson to where the ship's hull begins to form the side of the vessel, providing latitudinal strength to the structure.



**Frame(s):** formed from angle bars that rise upwards from the floors to the gunwhale (normally the upper edge of the side of the vessel, on the upper deck). Frames are located along both sides of the vessel from stem to stern and are also commonly known as the 'ribs' of a vessel.

**Side keelson(s):** perform a similar function to the keelson, but are located parallel to the centre keelson.

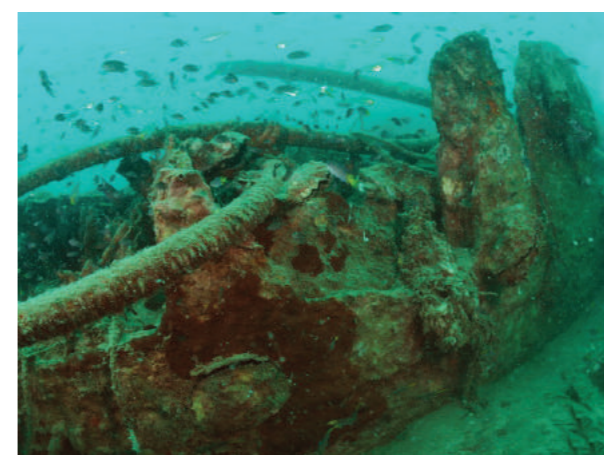
**Bilge keelson(s):** similar to side keelsons, but they curve upwards and inwards following the shape of the bow and stern.

**Stringer(s):** angle bar fixed along the interior longitudinal axis of the vessel's hull, usually riveted or welded to the frames.

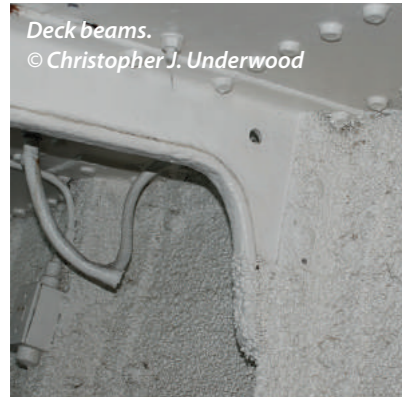
TOP: Floor section of a steamship wreck. © Christopher J. Underwood

MIDDLE: Frames and deck beams. © Christopher J. Underwood

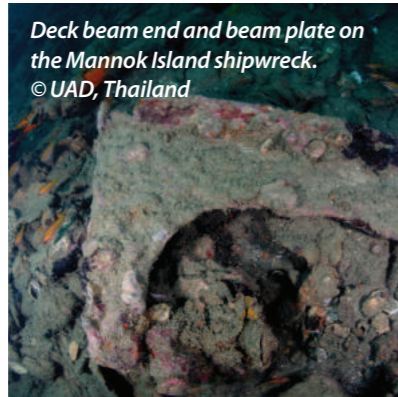
LEFT: © Frames of the Mannok Island Shipwreck site. © UAD, Thailand







Deck beams.  
© Christopher J. Underwood



Deck beam end and beam plate on the Mannok Island shipwreck.  
© UAD, Thailand



Deck.  
© Christopher J. Underwood



Pillars supporting the main deck of the SS Sarmiento. © Christopher J. Underwood

**Deck beam(s):** placed transversally across the vessel, they prevent the frames spreading outwards and also support the decks. They are riveted or welded to the ship's frames on the side of the vessel.

**Beam knee(s):** end section of a beam that allows it to be attached to the frame. They can be an integral part of the beam or as is the most common method, a separate piece (built knee) that is riveted or welded to the beam and frame.

**Deck(s):** constructed from flat metal plates (or wooden planking) that lay over the beams. There can be one or more decks depending on the size and purpose of the vessel.

**Pillar(s):** hollow or solid vertical posts that provide support for the deck(s). Where a central pillar is fitted, it will significantly increase the load capacity of the deck.



Small section of a deck or walkway in the engine room of the Mannok Island shipwreck. © UAD, Thailand

**Bulkhead(s):** longitudinal or transverse partitions that divide the vessel into compartments and can be made watertight to prevent flooding from spreading throughout a vessel.

**Plating:** forms the exterior shell of the hull, cabins partitions, decks and bulkheads. The plating is riveted or welded to structural components, such as frames and beams.

**Riveting:** the traditional method for joining the various components of metal ships prior to welding. Most joints are made by overlapping plates to form a lap joint.

There is archaeological evidence of riveting that dates to the Bronze Age in the construction of daggers (See Useful Websites: Portable Antiquities Scheme 2011).



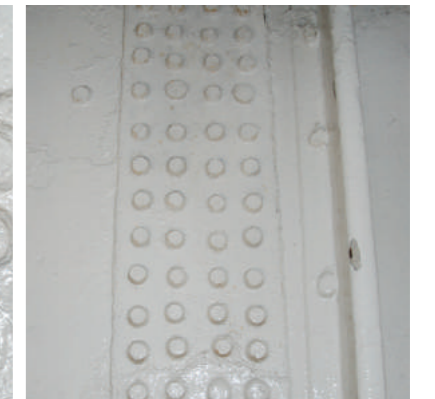
Watertight bulkhead (across the beam of the vessel).  
© Christopher J. Underwood



ABOVE LEFT: Riveted hull construction.  
© Christopher J. Underwood



ABOVE MIDDLE: Riveting pattern of an overlapping hull plate joint.  
© Christopher J. Underwood



ABOVE RIGHT: Butt strap riveted joint of non-overlapping hull plates.  
© Christopher J. Underwood



RIGHT: Hull plating of the Mannok Island shipwreck. © UAD, Thailand



**Welding:** a heat process that joins two pieces of metal together.

Welding was increasingly used during the First World War and became the predominant construction method as the twentieth century progressed. The *Fulegar*, built by the British shipbuilder Cammell Laird in 1920, was the first vessel with an entirely welded hull, and more than 2,700 Liberty ships of the Second World War were constructed fully utilising the process. As the riveting process absorbed a third of a vessel's production budget, replacing riveting with welding significantly accelerated the construction process and reduced labour costs.



ABOVE AND BELOW: Front and starboard side views of a steam (Scotch) boiler. © Christopher J. Underwood

**Propulsion:** The major components of a steam vessel's propulsion are found in the following order from bow to stern: boiler, engine, drive shaft, propeller and rudder.

NB. The engine and boiler can be positioned in the midship or stern sections depending on the size and function of the vessel.

**Boiler(s):** generate steam power that drives the engine(s). There can be single or multiple boiler units.

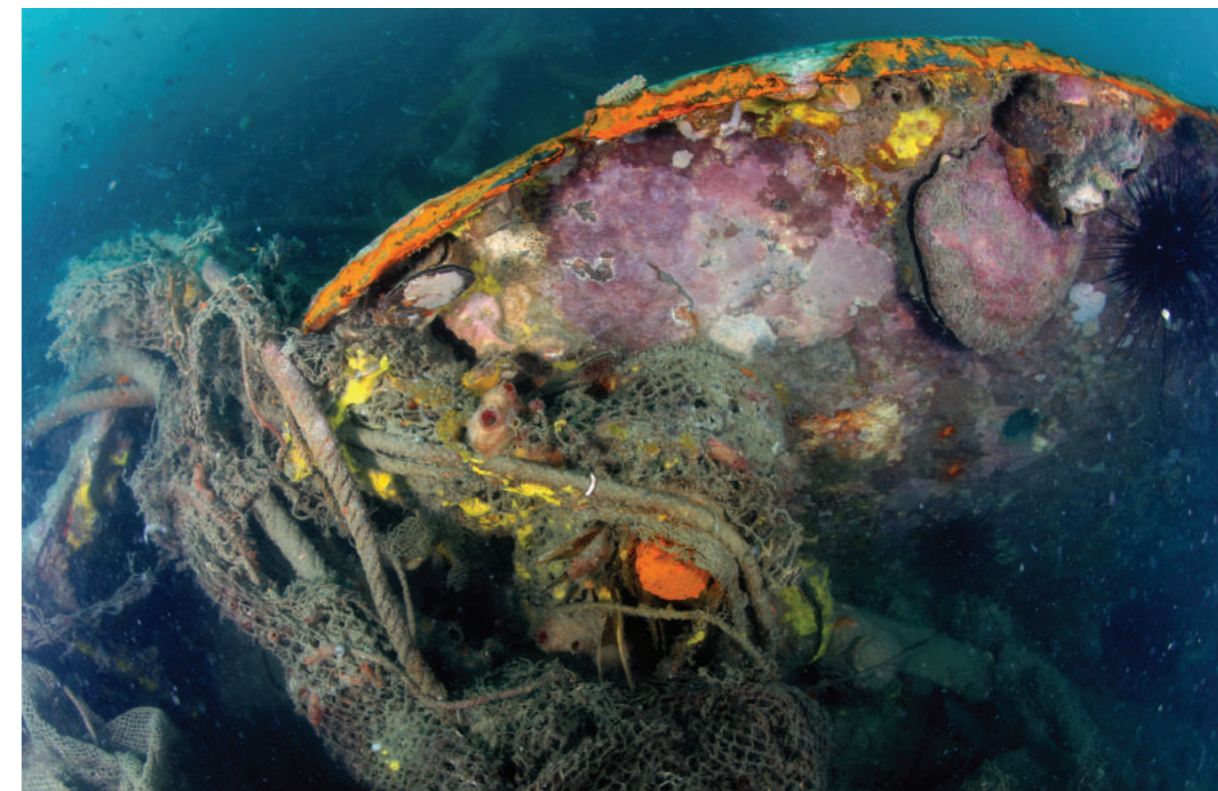
Although boilers with a similar design to the Scotch boiler appeared around 1830, it was the Scotch boiler that became the most common from the 1850s to the 1920s and can still be found in use today.

**Steam engines:** suitable for commercial (industrial) use and were first produced in 1712 by Thomas Newcomen. The original design was improved by James Watt between 1763 and 1775, but it was the emergence of the high pressure steam engine in the early 1900s that resulted in a rapid expansion of the use of steam power.



A section showing the steam pipes from a broken boiler. © Christopher J. Underwood

Damaged boiler on the Mannok Island shipwreck. © UAD, Thailand



**Trunk engines:** were common in warships as they could be installed horizontally below the waterline and therefore, be protected from gunfire.

HMS *Warrior* (1860), for example, is a single large capacity piston, mounted transversally across the vessel. It provided 1250 nhp (nominal horse power) giving 14.3 knots, with a maximum of 17.5 knots combining wind and steam.

A high powered version of the trunk engine was recovered in 1985 from the wreck of *Xantho* (1872) discovered in Australia. The engine had originally been designed for use in Crimean gunboats and was installed in the *Xantho* in 1871. The use of trunk engines began to decline with the introduction of higher pressure expansion engines in the second half of the nineteenth century.

**Compound engine:** the design was originally patented by Arthur Wolf in 1804. There are various claims about the invention of the marine compound engine and its first use that range between 1824 and 1850.

Double expansion or compound engines reduce the steam pressure in two stages, making them more powerful than earlier engines that only utilized the steam once. Although the name implies that they have two cylinders, these engines can have more than one operating at the same pressure, reducing to one or more at a lower pressure.

**Triple expansion engine:** is a compound engine that reduces the steam pressure in three stages. Each stage can have multiple cylinders.

The first multiple expansion engine was patented by Daniel Adamson in 1861. Triple expansion engines remained in widespread use from the 1880s until the middle of the twentieth century. These engines powered more than 2,700 Liberty ships during the Second World War and there are examples of working historical vessels continuing to be powered by the triple expansion engines, such as the SS *Shieldhall*.



The triple expansion engine of the *Fragata Sarmiento* (1893) produced 1800 horse power at 100 revolutions per minute, giving a maximum speed of 13 knots.

Other engine room components include the condenser, pumps, valves, auxiliary engines, gauges and many sections of steam pipe that join various components of the propulsion system.

**Drive shaft (or propeller shaft):** a cylindrical tube linking the engine to the propeller. The shaft passes through a watertight gland between the internal to the external part of the hull.

**Thrust block or box:** is a substantial metal component that is located on the drive shaft. The thrust block transfers the power of the propeller to the hull to prevent damage to the drive shaft.

**Propeller(s):** the origin of which is credited to Archimedes, is located at the end of the drive shaft and changes the rotational movement of the shaft that propels the vessel forwards, or backwards (if the movement of the drive shaft is reversed). They can have two, three, four or sometimes even more blades, which can be made from cast iron or bronze.

**Steering gear:** equipment for moving the rudder.



Drive (propeller) shaft. © Christopher J. Underwood



Thrust block (box). © Christopher J. Underwood



Two-blade bronze propeller. © Christopher J. Underwood

BELOW: Boat davits. © Christopher J. Underwood



**Davit(s):** used to lower or raise a ship's lifeboats.

**Derrick(s):** located on the upper deck. Used for loading and unloading cargo from the cargo holds or moving equipment.

**Pump(s):** used to remove unwanted water from a ship's hull and to improve stability by transferring water from one part of a vessel to another.



Ship's pump. © Christopher J. Underwood





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- Bingeman, J.M., Bethell, J.P., Goodwing, P. and Mack, A. 2000. Copper and Other Sheathing in the Royal Navy. *International Journal of Nautical Archaeology*. No. 29.2, pp. 218-29.
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## Appendix Summary

It is important to recognize that this appendix is aimed at providing sufficient information to enable students to carry out an assessment of the wreck site that is then used in the development of a management plan. The additional information is provided to place the content in an archaeological or historical perspective and is not intended to be a detailed study of naval architecture.



## Suggested Timetable

The information provided by this appendix can be presented in three parts; two in the classroom prior to the diving project, with the third part during the fieldwork.

10 mins	<p>Introduction to Metal Shipbuilding Technology</p> <ul style="list-style-type: none"> <li>- <i>The various factors that influence the design of vessels</i></li> <li>- <i>How vessels gradually evolved from wood to metal and from sail to steam in different geographic regions</i></li> </ul>
40 mins	<p>Part 1: Lecture</p> <ul style="list-style-type: none"> <li>- <i>Terminology and function of the main structural components of metal ships</i></li> <li>- <i>Terminology and function of the propulsion system of a metal steamship</i></li> <li>- <i>Terminology and function of deck fixtures and fittings</i></li> <li>- <i>Technical language concerning nautical terminology</i></li> <li>- <i>Demonstration of how a shipwreck can be identified by the study of its structure</i></li> <li>- <i>Discussion of how a metal shipwreck's structural integrity will deteriorate at varying rates according to the site's environmental conditions</i></li> <li>- <i>Illustration of the condition of structural components, fixtures and fittings that are commonly found on wreck sites</i></li> </ul>
30 mins	<p>Part 2: Knowledge Review</p> <ul style="list-style-type: none"> <li>- <i>Class participation session using an existing example drawing of a typical steamship. Students will be asked to list out main features of the vessel from the drawing.</i></li> </ul>
10 mins	<p>Concluding Remarks and Closure</p>

Part 3: Practical Assistance to help students understand and interpret the various features found on the wreck site, provided as required during the field project.

## Teaching Suggestions

The information on ship construction is kept at a generic level to avoid students becoming overwhelmed with the nautical terms and complexities of metal ship design.

Due to the commonality of many metal and wooden ship component names, trainers should highlight those parts of metal ships where there is overlap with wooden vessels introduced in Unit 14: *Asian Shipbuilding Technology* and its appendices

### Useful Websites

- HMS Victory: [www.hms-victory.com](http://www.hms-victory.com) (Accessed November 2011.)
- HMS Warrior: [www.hmswarrior.org](http://www.hmswarrior.org) (Accessed November 2011.)
- Liberty Ship Jeremiah O'Brien: [www.ssjeremiahobrien.org](http://www.ssjeremiahobrien.org) (Accessed November 2011.)
- Portable Antiquities Scheme: use of riveting during the Bronze Age [finds.org.uk/database/artefacts/record/id/276077](http://finds.org.uk/database/artefacts/record/id/276077) (Accessed November 2011.)
- SS Xantho: [museum.wa.gov.au/broadhurst/xantho-Shipwreck](http://museum.wa.gov.au/broadhurst/xantho-Shipwreck) (Accessed November 2011.)
- SS Shieldhall: [www.ss-shieldhall.co.uk/Shieldhall/Technical.html](http://www.ss-shieldhall.co.uk/Shieldhall/Technical.html) (Accessed November 2011.)





## Suggested Reading: Full List

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