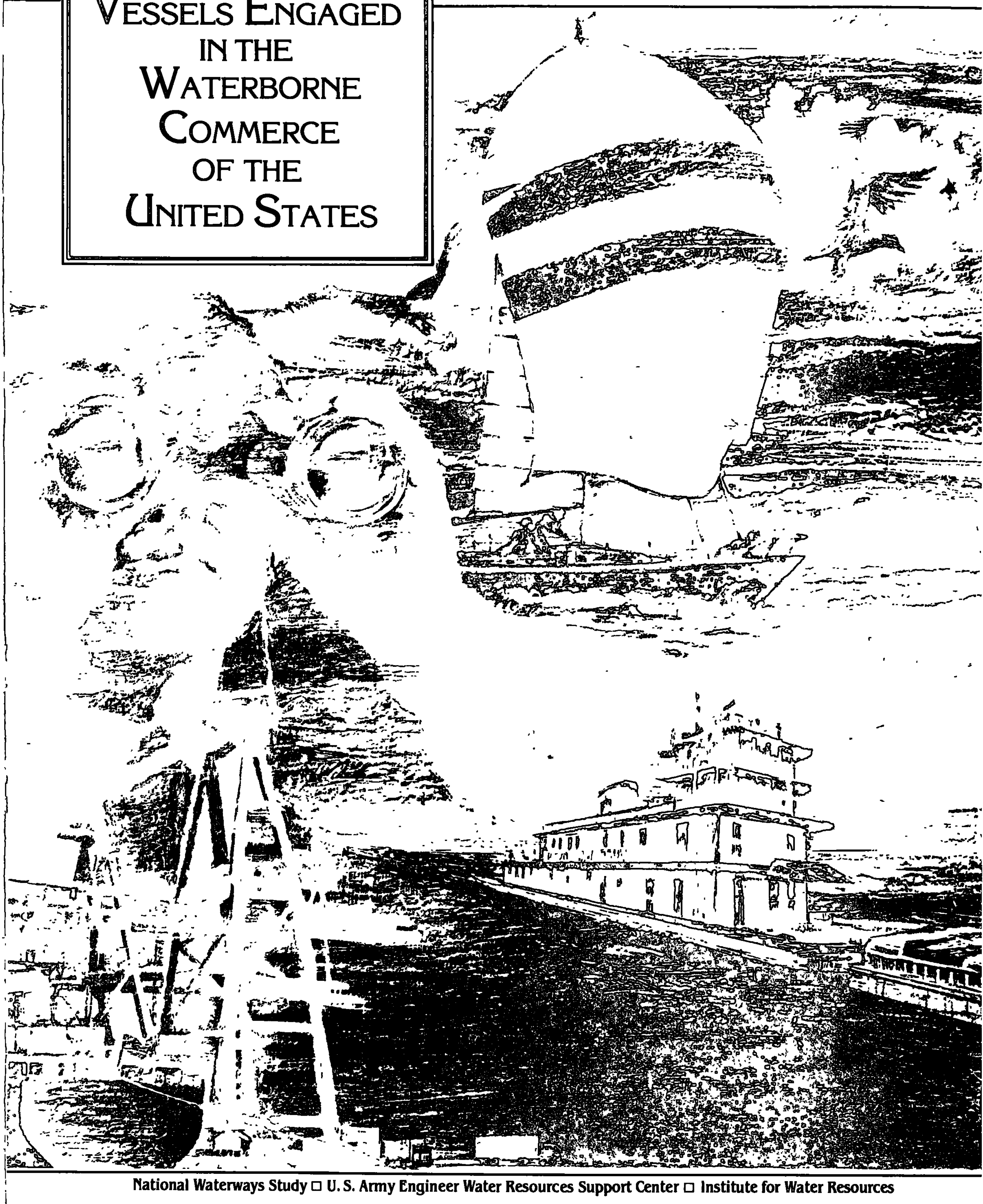
EVOLUTION OF THE VESSELS ENGAGED IN THE WATERBORNE COMMERCE OF THE UNITED STATES



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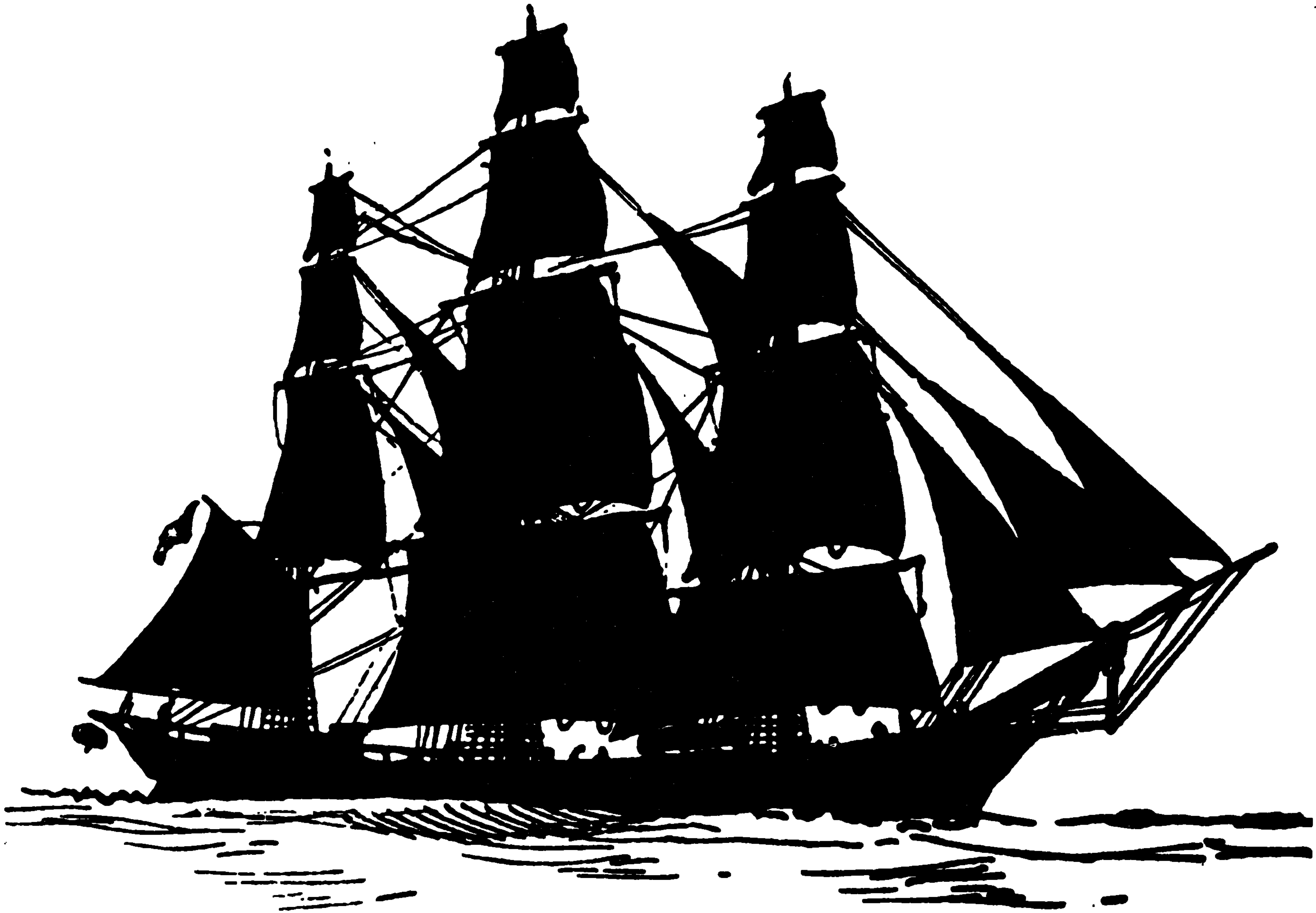

Ship

Evolution of the Vessels Engaged in the Waterborne Commerce of the United States

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January 1983
Navigation History NWS-83-3

National Waterways Study ◻ U.S. Army Engineer Water Resources Support Center ◻ Institute for Water Resources

AUTHORITY FOR THE NATIONAL WATERWAYS STUDY

The Congress authorized the National Waterways Study (NWS) and provided the instructions for its conduct in Section 158 of the Water Resources Development Act of 1976 (Public Law 94-587):

> The Secretary of the Army, acting through the Chief of Engineers, is authorized and directed to make a comprehensive study and report on the system of waterway improvements under his jurisdiction. The study shall include a review of the existing system and its capability for meeting the national needs including emergency and defense requirements and an appraisal of additional improvements necessary to optimize the system and its intermodal characteristics. The Secretary of the Army, acting through the Chief of Engineers, shall submit a report to Congress on this study within three years after funds are first appropriated and made available for the study, together with his recommendations. The Secretary of the Army, acting through the Chief of Engineers, shall upon request, from time to time, make available to the National Transportation Policy Study Commission established by Section 154 of Public Law 94-280, the information and data developed as a result of the study.

Evolution of the Vessels Engaged in the
Waterborne Commerce of the United States

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PREFACE

This pamphlet is one of a series on the history of navigation done as part of the National Waterways Study, authorized by Congress in Public Law 94-587. The National Waterways Study is an intensive review by the Corps of Engineers' Institute for Water Resources of past, present, and future needs and capabilities of the United States water transportation network. The Historical Division of the Office of the Chief of Engineers supervised the development of this pamphlet, which is designed to present a succinct overview of the subject area.

John T. Greenwood

JOHN T. GREENWOOD
Chief, Historical Division

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Chapter 1

EVOLUTION OF COMMERCIAL VESSELS

DURING THE COLONIAL PERIOD

The American colonial period spanned approximately two centuries, from 1600 to 1800. During this period the capital ship of European fleets was the great sailing ship which had emerged as the most effective military vessel as well as the most efficient merchantman. The seagoing oared galleys had gradually declined in utility and, by 1600, they were seldom found except in the Mediterranean where large crews could be supplied for short-range voyages. This type of ship, with its long low profile, was cramped, confined, and, lacking both sturdiness and seaworthiness, ill-suited for long voyages in rough seas.

The galley was no match for the larger sailing vessel which could carry more cargo and heavier armament. The ship, with its greater beam and displacement, could carry the sail needed for greater speed and maneuverability. Yet the capability to use oars when becalmed was retained in some for many years after oars had been abandoned as a primary means of propulsion and, for these vessels, the name "galley" persisted.

The sailing ship was thus the mode of transport for the early colonists. These included Spanish, populating the shores of Mexico, the West Indies, and the islands and mainland bounding the Straits of Florida; the English, settling from Georgia north to Massachusetts; the Dutch in Pennsylvania, New Jersey, and New York; and the French in Maine, New Brunswick, Nova Scotia, and Quebec.

Early Shipbuilding in the English Colonies

The Spanish vessels were designed generally as replicas of those of the mother country. This same practice was followed by the English colonists when they too began building ships in the mid-seventeenth century. Although numerous small craft were constructed in North America for fishing and for inland water travel, it was not until the 1640s that the colonists began building ships for use in overseas and coastal trade. The Civil War in England provided an opportunity for the colonists to capitalize on England's distraction to invade this profitable market.

Unlike the Spanish, the English colonial shipyards were privately owned and, despite a slow start, flourished by 1700 with many small yards building craft such as the pinnace, shallop, ketch, sloop, gälley, pink, and skiff. These types had configurations that changed with both time and location. However, the descriptions below are generally representative.

Small craft used for trading in protected waters, both along the coast and inland, were generally rowed or paddled and not fitted with sails. Among these were dugouts resembling square-sterned ships' boats and called boat-canoes; there also were sharp-sterned dugout canoes. The birchbark Indian canoes were generally confined to the waters of eastern Maine and the Canadian maritime areas. Skiffs were small rowed craft seldom fitted with sails.

The name pinnace applied to galley-ships in the sixteenth and seventeenth centuries, but by the beginning of the eighteenth century it was used to describe an oared, long, narrow ship's boat or a decked craft driven by oars or sail. The sailing version of the pinnace was rigged with two masts carrying square sails, a square spritsail, and a lateen mizzen.

Shallop described vessels ranging from a small open boat to a large decked-over fishing boat or a boat engaged in coastal commerce. The typical shallop evolved into a two-master rigged fore and after with gaffsails and no jib, the forward gaffsail being the smaller. When operating in protected waters, a lateen rig was occasionally used.

The ketch of colonial times was a two-masted, fore-and-aft rigged, square-sterned sailing vessel. A relatively small ship, since records indicate that crews were small, the ketch was used both for fishing on the Grand Banks and for trade. In addition to main and mizzen gaffsails of approximately equal size, it is probable that one or more jibs were used. Early in the eighteenth century the name ketch disappeared to be replaced with schooner. It is believed that this was merely a change in designation rather than a change in the craft itself.

The sloop was commonly employed in the coastal and West Indian trade. A single-masted vessel up to 65 feet in length, the sloop carried a gaff mainsail and two or more jibs. They were built both on the North American mainland and in the West Indies during the close of the seventeenth century and were purported to be extremely fast sailers. The pink was rigged as a ship, brigantine, or sloop, and could be recognized by its sharp stern with bulwarks carried abaft the stern post. It was a predecessor of the schooner-rigged American pinky.

Shipbuilding Materials and Tools

Significant differences between colonial and English construction began to evolve as the colonists utilized the materials available to them. In the northern colonies the shipbuilding timbers were oak, cedar, white pine, spruce, elm, maple, chestnut, and juniper (hackmatack). The Chesapeake Bay shipyards used mulberry, cedar, chestnut, laurel, oak, and southern pine. In the southern colonies such local woods as cypress, live oak, and long-leaf yellow pine were more prevalent as shipbuilding materials.

Shipwrights gradually discovered how to take maximum advantage of these timbers, but they were unwilling, because of cost and time constraints, to age them properly. As a result, many ships built during the latter half of the seventeenth century were relatively short-lived and, if the ships saw service in the Florida Straits and the West Indies, they might deteriorate much more rapidly due to the ravages of rot and marine growth.

The common hand tools used by the colonists for other building activities were also employed in shipbuilding. These included the hatchet, axe, handsaw, plane, adze, maul, hammer, chisel, scraper, square, and measuring implements. A pitsaw was used for cutting out planks. Where available water sources permitted, saws were driven by water power but hand-work rather than power-work was the general rule for most shipyards.

With these materials and tools the shipbuilding skills of the seventeenth century colonists continued to improve, and the expanding maritime trade, the fishing industry, and inland upriver exploration created a constant demand for different types of small craft. These included mostly vessels of English origin such as the wherry, whaleboat, barge, yawl, longboat, and cutter. Two types of craft of American origin evolved from this period--the dory and the moses boat. The dory was a flat-bottomed skiff that evolved from the planked canoe used by the seventeenth century lumberman; the moses boat was a square-sterned rowboat with a rocker keel and a high sheer used as a lighter to handle casks.

The Coastal Trade

During the entire colonial period, the various colonies were quite isolated, particularly in terms of overland transport of goods in quantity. All of these colonies, however, were well served by ports which provided safe harbors for interconnecting coastal trade.

The small size of these ports and the limited back country they served made it difficult for them to assemble sizeable cargoes for foreign transport. Yet the combined exports of a number of these enclaves, as well as the imports they needed for survival, generated a natural requirement for coastal trade by small ships.

Both independent coastal traders and branches of larger merchant groups began developing vessels for the coastal trade, each vessel adapted to the particular coastal area that it served. The earliest coasters were ketches, sloops, and large shallops. There is evidence that the ketches were, in fact, small schooners. All were fore-and-aft rigged for maneuverability in the coastal areas they served.

When trade was halted by the Civil War in England, the colonists increased their coaster fleet and extended its range to encompass the West Indies. Vessels proceeding to and from the West Indies could easily pick up and drop off cargoes at a number of ports along the way. River trade developed as a feeder service and shoal-draft sloops, shallops, gundalows and flats, or scows, ran up and down the James, Delaware, Hudson, and other rivers along the Atlantic coast.

After 1740 there was a marked increase in the size of coastal trading vessels and, although sloops and schooners predominated, ships, brigs, and brigantines were also used.

Development of New and Faster Vessel Types

At the beginning of the eighteenth century, the international situation was unstable and ships flying any flag had to be prepared to fend for themselves should the ships of any other nation decide to expropriate their cargoes. One answer was to build large fleets of heavily armed ships and to run in convoy through dangerous waters. The other answer, particularly for those involved in smuggling, was to increase the speed and maneuverability of their ships to enable them to outrun any potential enemy.

By 1700, the small vessels plying between the Chesapeake and the West Indies were already speedy sailers. The sloop, variously called the West Indies sloop, the Jamaican sloop, or the Bermuda sloop, retained its original characteristics except for slight alterations to increase its speed. With a keel length of about 65 feet, the overall length from tip of bowsprit to tip of the mainsail boom might be as great as 145 feet. These small vessels carried large amounts of sail. The single mast was heavily raked and carried two or more headsails, a large gaff mainsail with boom, a square course and topsail, and a topgallant sail. This type of sloop was built on the Eastern Shore of Maryland and Virginia, and on the western shore of Chesapeake Bay, and in Delaware. The vessel's large sail complex, however, required an excessive number of men which decreased the sloop's carrying capacity and therefore its efficiency as a cargo ship.

Another fast-sailing ship developed on the Chesapeake was a schooner-rigged vessel known as a Virginia pilot boat or pilot schooner. The length of these vessels ranged from 35 to 55 feet. The two masts, unsupported by rigging, were raked well aft, and the bowsprit was relatively short. They carried a large jib, a loose-footed and overlapping gaff-foresail, a boomed gaff-mainsail, and a large main-topmast staysail between the masts. This Virginia pilot boat was a schooner as were other fast sailing ships built in the Chesapeake region and on the shores of Delaware, New York, and New England prior to the Revolutionary War.

These schooners varied somewhat with the areas in which they were built and, in some cases, the sail plans differed to include square sails. The Chesapeake schooner was built with a considerable drag of keel and reached lengths on the order of 80 feet from stem to sternpost. They had a large deadrise, a well-rounded bilge, and fair amount of tumble home giving the midship section a heart-shaped appearance. They had a rounded-stem profile, high bulwarks pierced for as many as 14 carriage guns, and high quarterdecks running a short distance forward of the squared-off transom. Moldings and carvings were minimal. They carried an immense amount of sail in a square-topsail, schooner rig configuration that might comprise two or more headsails, fore and main gaffsails, main-topmast staysail, fore course, square topsail, topgallant and occasional additional sails.

The Marblehead schooner evolved from Banks fishermen that relied upon high speed to get their catches ashore. These ships had a larger cargo capacity than their Chesapeake-built counterparts. The midship section was of similar configuration, but they carried a bit more beam and draft for their length. The masts were raked, but were supported by standing rigging. When used for trade, they were often fitted as square-topsail schooners since the masts had sufficient support to carry sail well above the deck level. Since the Marblehead schooners were less likely to become involved in combat, either when fishing or engaged in trade, they carried fewer guns or none at all.

These fast-sailing schooners were used for fishing, for coastal trading, and for trade with the West Indies. When larger, longer-range, fast merchantmen or privateers were required, it was natural that the colonial shipwrights should use similar hull forms enlarged as necessary to carry additional cargo and more extensive canvas. Such large, fast, full-rigged ships existed in the colonies long before the Revolutionary War. Although original plans of these ships are unavailable, a number, used as privateers, were captured by the British and taken into the British Navy. During their conversion, meticulous drawings of hull form and details were prepared.

As one example, the Rattlesnake, designed by John Peck and built at Plymouth, Massachusetts, was captured by the British early in the war. She had the heart-shaped midship section of a schooner but bore the three masts and sail plan of a full-rigged ship. A similar but larger vessel of American origin was the Barbados, also ship-rigged. Two large American two-masted schooners captured and taken into the British Navy were the Swift and the Berbice. The principal dimensions of these four vessels are as follows:

Ship	Rattlesnake	Barbados	Swift	Berbice
Rig	Ship	Ship	Schooner	Schooner
Length on deck	89' 3"	97' 7"	75' 6"	72' 9"
Beam	22' 4"	24' 11"	20' 10"	20' 8"
Depth of hold	8' 10"	10' 7"	7' 9"	8' 0"

Hull Design Evolution During the Colonial Period

During the seventeenth and eighteenth centuries there were significant changes in the hull forms of American seagoing sailing ships. They ranged from the stubby full-bodied hulls of the Jamestown and Plymouth ships to the sharp-hulled sloops and frigates that formed the nucleus of fighting ships of the Continental Navy.

At the beginning of the colonial period, topsides had a steep tumble home; bows and sterns showed a marked upward thrust, and much material was wasted in gingerbread carvings at bow and stern that generated spray and added resistance. These characteristics, inherited from the British, began to change as the colonists' shipbuilding activities accelerated during the mid-seventeenth century. Tumble home along the midlength was reduced by lowering the bulwarks; the bow was lifted, and the beak shortened to provide a more graceful cutwater. The bulky forecastles gradually disappeared leaving only a modest amount of space required for crew shelter.

By 1650, the huge aftercastles with three decks extending from the mainmast to aft of the mizzenmast were gradually cut down. It was realized that they not only wasted space and blanketed the sails, but also created a sail area of their own that made maneuvering difficult in beam winds. After 1670, these structures were both aerodynamically and aesthetically improved by removing the two lower tiers so that only a poop, level with the upper deck, remained.

Improvements were also made in the underwater body at the stern giving cleaner, sweeping buttock lines in the run. The changes not only reduced eddy-making resistance, but improved the flow to the rudder thus increasing maneuverability. Providing a ship design with a proper draft was a continuing compromise between developing enough lateral resistance to be able to sail close to the wind and being able to run the ships into shallow harbors. It was generally contended that a large keel depth contributed to improved speed and maneuverability. However, for a given displacement, the greater the draft, the less the beam, and hydrostatic stability would suffer. On the other hand, a broad beam and shallow draft, while giving increased stability and access to shallower waters, meant less longitudinal strength, less seaworthiness, and a tendency to drift downwind when running close hauled.

Chapter 2

SAILING SHIPS IN INTERNATIONAL TRADE

The maritime industry during colonial times continually fought an uphill battle for survival. Every possible obstacle was placed in the way of the American colonist who attempted to make a legal livelihood in maritime trade with other countries of the world. The British Acts of Trade and Navigation were tailored to maximize the profits flowing into England and to minimize those which flowed in the direction of its colonies. For example, it was illegal for the colonist to export tobacco to any country but England and there he was forced to accept whatever price was offered. Similarly, his return cargoes could not be obtained from other than British sources.

American colonials were likewise prevented by law from the lucrative trades of Africa, South America, and India. Subject to varying restrictive conditions he might do business in a few ports around the Mediterranean and in the West Indies, but even in these trades his goods were subject to embargoes, seizures, and other prohibitions and restrictions. Under these conditions it is not surprising that the smuggling trade flourished and that American shipowners were more prone to avoid compliance with the laws than to accommodate their activities to them.

With the Revolutionary War successfully concluded in favor of the United States, the shipowners had every right to expect that this untenable situation would improve and the restrictions to free use of the seas would be lifted. But the seizures of men and vessels continued and worsened as American shipowners launched new trading ventures with larger and more commodious ships. France, England, and the Barbary States were the worst offenders, but Spain, Denmark, and other nations were not without guilt in their interference with American worldwide trade.

In matters of foreign policy the United States was a novice. Diplomacy accomplished little toward providing protection for American ships and seamen. Militarily, the new nation was equally helpless at sea. Its small naval fleet had been decimated by the war's end. Once again the Yankee shipbuilders and seamen were forced to return to the prewar and wartime practice of using small, fast ships to build the seagoing muscle needed to compete with the maritime powers of the world.

Ancestors of the Clipper Ship

Although a treaty ending the American Revolution was not signed until 1783, hostilities effectively ceased after the surrender of the British at Yorktown in 1781. In late 1782, the Nantucket ship Bedford had left port with a load of oil, picked up word in France that the war had ended, and entered British waters on the sixth of February ready to do business; within a few days there were three American vessels in the River Thames anxious to begin trading activities.

The Americans moved rapidly to reestablish trade with Britain and with other European countries. However, they were faced with many of the same problems that they had encountered under colonial rule, and, in addition, lacked the large ships needed to carry on efficient waterborne commerce.

Trade with China was initiated with the departure of the Empress of China on February 22, 1784; after a six-month passage, she entered the harbor at Macao. This trade grew very slowly because of the large, long-term capital investment required. As many as 15 months might pass before receiving a return cargo on which a profit could be made.

Because of the actions of foreign ships and of pirates in commandeering the cargoes of the larger, low-speed, sailing ships, the Yankee traders reverted to the faster, smaller schooners that had proved so successful in pre-Revolution smuggling and wartime privateering operations. From the Marblehead schooner and the Virginia pilot boat there had evolved in the 1740s a topsail schooner known as the Baltimore clipper. Schooners of this type were extremely successful as privateers during the sea battles of the Revolutionary War. Carrying large areas of canvas, these ships could race along at better than 12 knots and their deep draft allowed them to sail closer to the wind than other vessels. Although their cargo capacity was limited, the Baltimore clippers did much to add to the tonnage carried by the American merchant marine through the close of the eighteenth century and on into the first of the nineteenth century. From the Revolution through the War of 1812, these speedy schooners not only served the young nation well but were copied frequently by European shipbuilders.

When peace came at the end of the War of 1812, the Baltimore clipper was gradually replaced with ships that were slower, but had a greater carrying capacity. However, they still served trades in which speed was important--running slaves, smuggling opium, and carrying perishable fruit and coffee from the West Indies and South America.

To service growing international trade, the movement of goods from the back country to the seacoast and from the smaller to the larger ports also increased rapidly. After 1825, sloops were relegated to river and estuary trade and the size of coasters increased, with a larger and larger portion of the coastwise trade being served by schooners and schooner-rigged vessels.

New England Trade with the West Indies

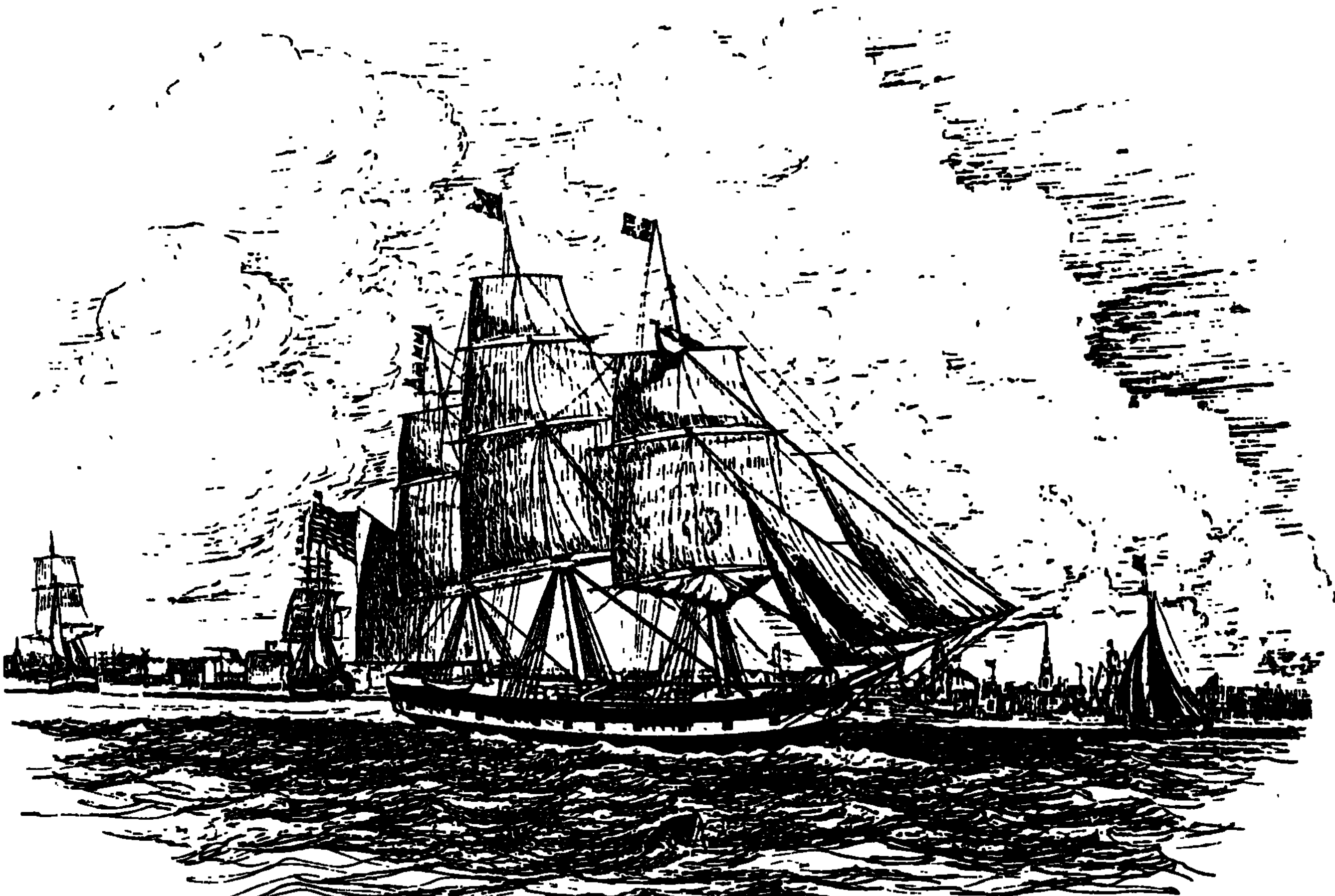
The New England trade with the West Indies was carried mostly in topsail schooners and brigantines. The latter, two-masted ships, carried square sails on the foremast and a square topsail and fore-and-aft gaff-sail on the mainmast. Until about 1830 the Carribean was infested with pirates. The New England-West Indies trade, although employing larger ships than those of the southern states, was still concerned with having sufficient speed to get clear of the predators. Consequently, their ships had a sharp, slender, deep-hulled design to take them out of harm's way. The Chesapeake-West Indies trade used Baltimore clippers for this purpose.

All of the ships involved in the West Indies trade continued to be well armed until the American and British navies gradually succeeded in suppressing piracy in the Carribean. Speed eventually lessened in importance and ships' beams broadened as carrying capacity became the most sought-after ship characteristic.

It can be seen that the Yankee trading vessels, working in both the coastal and international trades, had a preoccupation with speed because their economic lives depended upon it. This was true throughout the colonial period and extended well into the nineteenth century. During that same period, the British merchantmen characteristically made an average speed of two to three knots, with maximums no greater than five or six knots. Yet, although the faster American ships were more advantageous to their owners in turning a quick profit, the British merchantmen, protected by the Royal Navy, could be counted upon to bring their cargoes in and to maintain a relatively steady flow of goods.

North Atlantic Packets

In colonial times, and on through the War of 1812, the sailings of commercial vessels were irregular and depended upon when the ships acquired enough cargo to make the trip worthwhile. Unfavorable weather also caused delays in sailing. This irregular operating schedule was particularly unsatisfactory for the transport of passengers and mail. As a result, in 1755, the British established a mail packet service using brigantines operated by the Post Office. The French established a similar service.



YORKSHIRE
First Class Packet Ship

LBP	174
Extreme breadth	36' 8"
Depth of hold	21' 6"

Designed and built by William H Webb, 1843

Neither of these services was particularly fast, and the ships were very uncomfortable for passengers. American shipowners soon recognized that there was money to be made in a service that crossed the Atlantic on a regular schedule. In 1818, four wealthy New York merchants organized a transatlantic packet service with four ships. The key feature of this service was that, regardless of weather or the amount of cargo on board, a ship was to leave port on the first day of each month.

This first venture was known as the Black Ball Line and its ships carried the insignia of a black ball on house ensigns and fore-topsails. The Red Star Line, the Swallowtail Line, Le Havre Line, and others soon followed, providing service of two or more lines between New York, Liverpool, London, and Le Havre.

To accommodate the cargoes carried, these ships were necessarily full-bodied but speed was still important to meet the high level of competition that grew between the various lines. As a result, the ships were driven hard and the sails were reefed in only when absolutely necessary. The early packets were on the order of 500 register tons or less, with lengths of 110 to 115 feet on deck and beams ranging between 28 and 31 feet.

For the transatlantic packets, a high deadrise was used due to the concept, at the time, that this tended to increase speed. However, in the coastal packet trade, which developed between New York, Philadelphia, Baltimore, Charleston, Savannah, Mobile, and New Orleans, deadrise was reduced to gain more displacement at shallower drafts because of the bars at river entrances and the desire to get maximum displacement into ships of lengths that could negotiate the rivers leading to these ports.

By 1843, packet ships of 180 feet in length were being built for the transatlantic trade; by 1855, lengths exceeded 190 feet. The ships of this era had full midship sections, a good length of middlebody combined with fine ends, and with the maximum section forward of amidships. They were flush decked, with two and three decks below giving ample longitudinal strength to the longer hulls. They were strongly built and diagonally strapped to support the heavy spars that could carry ample canvas in the heaviest of winds.

But the packet ships were the first transatlantic sailers to bow to the power of steam. They thrived on their ability to maintain a more regular schedule, a dependability demanded for passengers, mail, and special forms of cargo. Yet they were still at the mercy of the wind and, although driven to their utmost to establish one speed record after another, their trips often took much longer than the passenger and merchant trades would tolerate. At the same time, the early steamers, which could continue under power when the wind failed, began to develop some degree of reliability. Just after mid-century, the era of the sailing packet ship began to close. Over 100 had been built.

The American Clipper Ship

In the 1830s, the needs and desires of the American maritime industry to build fast sailing ships were reinforced once again by economic necessity and the lure of large profits. High freight rates could be obtained by transporting specialized cargoes over a number of long treacherous routes. The trade in opium from India to China required sailing ships capable of making fast passages to China in all seasons. The tea trade from China to Europe and America was particularly lucrative; each season the first consignment to arrive commanded extra-high prices. The gold discoveries in California in 1848 and in Australia in 1850 created an immediate demand to move men and equipment to remote areas of the world. The clipper ship (not to be confused with the Baltimore clipper) was developed to capitalize upon these trades.

The clipper-ship era was remarkably short. For American ships, it began in the 1840s and ended in the 1860s. The British clipper hung on for another decade, but, in the 1870s was no longer a viable factor in ocean commerce. Although the clippers were beautiful ships, built with care, and sailed with pride, they were over-specialized to the point where they faded out when the trades they served died out. The clipper ships carried relatively little cargo. To make the high speeds for which they were intended, they had to be driven hard, day and night, stressing spars and sails to the breaking point. They required large crews. They cost too much, both to build and to run. When the economic conditions that created the clipper eased off, her day was done.

Nevertheless, at the peak of their glory, the American clippers were the fastest ships that had ever sailed. They often made the New York to San Francisco run in less than 100 days and logged speeds as high as 19 to 21 knots, better than most of today's smaller racing yachts.

The clippers evolved from the Baltimore clipper of the 1820s and the packet ships of the intervening years. The beamy, bluff-bowed packet was transformed by mating its three masts with a full ship's rig and blending it with a scaled-up model of the sharp-hulled Baltimore clipper. Actually, there were three hull types that deservedly bore the generic name of clipper ship during this period: the extreme clipper; the clipper; and the medium, or half-clipper.

The extreme clippers had the highest speed potential and the least cargo-carrying capacity. Their deep hulls closely resembled the Baltimore clipper with marked deadrise and fine ends. Such ships were the Samuel Russell, Nightingale, Sea Witch, Watch of the Wave, Staghound, and Gazelle.

The clipper ships' hulls were more practical, with greater displacement-length ratios and beams. They tended to combine a reasonable cargo capacity with their speed and thus proved to be more profitable vessels in the trades that they served. Such ships were William H. Webb's Comet, Young America, and Invincible; Donald McKay's Flying Cloud, Sovereign of the Seas, and James Baines; and Samuel Pook's Surprise, Red Jacket, and Belle of the West.

Medium, or half-clippers were an attempt to further increase cargo capacity without paying an undue speed penalty. These clippers closely approached a conventional full-formed ship. Examples were the Nor'Wester, Andrew Jackson, and Golden Fleece.

During the 1850s, 395 clippers were built. Demand reached its peak in this decade, bringing fame to American shipbuilders and architects. John W. Griffiths was credited with originating the clipper ship. William H. Webb, who like other shipyard owners built other types in addition to the clipper, produced both the largest number and the greatest tonnage of ships from a shipyard of that time. Donald McKay, best known for high speed designs, introduced steam-powered shipbuilding machinery and reduced building time.

The simplicity of ship design in that period continues to awe naval architects. Principal dimensions were simply a matter of experience. The usual method of obtaining lines was to carve out a half-model made of layers of wood; then, when it had reached a shape satisfactory to the critical eye of its creator, the layers were separated, half-breadths measured off and sent to the mold loft. Scantlings were selected by rule of thumb. Classification-society rules were just beginning to develop. Every shipwright knew how to construct a ship and its many component parts; detail drawings were seldom used. The only plan drawn, in most cases, was a rough draft of the spar dimensions, made as a guide for the sailmaker.

Weight calculations were not considered; they were not important anyway, for the fine-lined sailing ships were long on displacement and short on cubic capacity. For stability, in some clippers, permanent rock ballast was carried, more could be added if the shipbuilder's estimate of sail-carrying power proved over-optimistic.

The largest of McKay's clippers was the Great Republic, which was the largest clipper ship in the world. She had a length of 334 feet, a beam of 53 feet, and a depth of 38 feet. Unlike other clippers, which were three-masted and ship-rigged, the Great Republic was four-masted and rigged as a barque with square sails on the fore-, main-, and mizzenmasts and fore-and-aft sails only on the jiggermast. Consider the proportions of the mainmast alone: the lower mast, 131 feet; the topmast, 76 feet; the top gallant mast, 28 feet; the royal mast, 22 feet; and the skysail mast, 19 feet. The mainyard was 120 feet in length and the foreyard was 110 feet long.

The Great Republic was launched in Boston in October 1853 and then towed to New York. When nearly ready to sail on her maiden voyage, she caught fire and was severely damaged. Later rebuilt, her register tonnage was reduced to 3,357 and her carrying capacity lowered by nearly 2,000 tons. She was, however, still the largest sailing vessel in the world and completed her maiden voyage from New York to Liverpool in nineteen days. She operated under charter to the French government as a troop-ship in the Crimean War; later worked in the California trade; and, during the Civil War, was chartered by the U. S. government. Sold to a Liverpool firm and renamed Denmark in 1869, she was abandoned at sea in 1872.

This brief history is not atypical of many of the other famous clippers of the day. In their first few years, when the demands were great and the profits high, the American clippers broke one record after another in runs from New York to San Francisco, Liverpool to Australia, New York to China and in many other high-speed transits across the oceans of the world. Yet, as the reliability of steam propulsion increased, and as the demand for high-speed movement of specialized cargoes waned, the famed clipper ships gradually drifted into less glamorous trades and finally slipped into oblivion.

But this two-decade period in the maritime history of the United States will not be forgotten. These ships were a tribute to the men who designed them, the men who built them, and the men who sailed them. Although the term "clipper ship" is a generalization, there seems to be agreement that when the term clipper is applied to a ship, that ship is supposed to have possessed three prime essentials. First, she was 'sharp-built'--designed as a hull for speed rather than cargo space. Second, she was extremely heavily sparred in order to spread to a far larger area of canvas than ships of equal size were accustomed to spread.

The third essential involved the operation of the ship. Her captain had to be almost obsessed with the need to make all possible speed without regard for his crew or for the stresses to which the ship was exposed. He would extend his rig and spread of canvas to the maximum and hang on as long as the ship was physically able to hold together in weather where lesser men and lesser ships would fall off and ride out the sea until more comfortable conditions prevailed.

Phasing Out the Merchant Sailing Ships

The maximum size of sailing vessels was restricted to some extent by the materials from which they were built. It was difficult to build enough longitudinal strength into a wooden ship to resist the bending movements and torsional loadings imposed by the seaway and by the forces acting on the sails. It became commonplace in the mid-nineteenth century to substitute metal fasteners for the wooden treenails that had been used throughout history to join parts of wooden ships. The Great Republic could not have been built without the extra hull strength provided by crossed diagonal iron straps.

The idea of composite ships, as the wood/iron construction was called, originated in 1839 in a patent issued to William Watson of Dublin. The patent described "an improvement in the construction of ships" in which the ribs (transverse frames) were formed of iron angle, or "T-iron," bars bent into suitable shapes. The skin, or outer casing, of the vessel was to be of timber planks fastened to the ribs by rivets or screw bolts and nuts. In a patent issued to John Jordan of Liverpool in 1849, the composite construction concept was extended to longitudinal framing. He patented the use of a continuous iron plate keel running the full length of the ship and continuing up the stem and stern posts. To the lower side of this iron keel plate was bolted a wooden keel. The iron frames also were bolted to it. Jordan also proposed iron plates to strengthen the wooden deckbeams. Additional proposals included the use of copper bolts in such a way as to isolate them from the iron to prevent galvanic action; similar contact was avoided between the iron frames and the copper sheathing on the outside of the hull.

With composite-ship design, the size of ships could be increased and the relative hull weight decreased; many of the later clipper ships were of this construction. And, the introduction of more complex structural design factors involved in the combined use of different hull materials encouraged the committee of Lloyd's Register of Shipping to issue "Rules for the Construction of Composite Ships" in 1868. Lloyd's Register had a direct relationship with the Lloyd's group of insurance underwriters and therefore its rules were adopted by shipowners as a prerequisite of insurability. The American Bureau of Shipping, established in 1862, published similar rules and compliance was insisted upon by most American insurers.

As the full ship-rigged clippers took over the profitable high-speed international trades in the 1850s, the coast trade shifted first to schooners and then, gradually, to steam-powered vessels. However, schooners were found to be economical carriers of such bulk commodities as grain, lumber, coal, cotton, and bricks.

The earlier schooner hulls resembled the clipper ships but, as their use in bulk cargo trades increased, the hull forms began to fill out, enlarging carrying capacity and operating at lower and more economical speeds. They were usually designed for specific operating areas, some with deep hulls and keels, and others with shallow drafts and centerboards.

Schooners were successful and profitable as bulk coasters. For over 100 years they operated on the Atlantic and Pacific seaboards and in the Great Lakes and, although they were not generally considered viable for long ocean voyages, some did travel from American ports to China, Australia, West Africa, and South America.

During the 1870s and 1880s, their size, and the number of masts they carried, gradually increased. The David Dows, built in 1881 in Toledo, Ohio, had a register tonnage of 1,418 and a length of 265 feet. The Dows had five masts and was the largest schooner in the world at that time.

The first six-masted schooner was the 3,401 ton Eleanor A. Percy, built in 1900 at Bath, Maine. She was 323 feet long and had a beam of 50 feet. In 1907, the six-masted Wyoming of 3,731 tons was built by Perry & Small; at 330 feet she was the longest wooden sailing vessel ever built. She carried several steam winches on deck and could be handled by a crew of eleven men.

Only one seven-masted schooner was built--the steel-hulled Thomas W. Lawson, 5,218 tons, built by the Fore River Shipbuilding Company. The hull was 395 feet long with a beam of 50 feet. Each of the seven masts comprised a 135-foot steel lower mast and a 58-foot Oregon pine topmast. Sail-handling was accomplished with the aid of six steam winches and a crew of only 16 men was required. The Lawson, chartered for carrying case oil across the Atlantic, capsized after running into trouble in the Scilly Islands in December 1907.

The last American-built wooden sailing ships were a group of square-riggers constructed in Maine and Massachusetts shipyards and known as the Down Easters. They were capable of a good turn of speed and were sufficiently full bodied to carry ecomonical tonnages. Primarily bulk carriers--grain, nitrate, and sugar, they were based on both the East and West coasts and served such ports as San Francisco, New York, Liverpool, Honolulu, Callao (Peru), and Hong Kong.

The Down Easters were built between 1870 and 1895. The last deep-sea, square-rigged, wooden vessel to be built anywhere in the world was the Aryan, 2,124 tons, built near Bath, Maine. Launched in 1893, this ship was lost by fire in the Pacific in December 1918.

The first of the iron sailing ships was built in 1838 and their number gradually increased. Several of the later clipper ships were of iron construction. The iron ships could not be copper sheathed as were the wooden ships; cathodic interaction of the two metals caused corrosion. But, without the copper sheathing, marine growth formed rapidly on the underwater hulls of the iron ships. It was not until a reasonably effective antifouling paint had been developed that these ships could operate for any length of time without drydocking.

Yet the iron ships, because of the strength of the material, could be built longer in proportion to their breadth and depth. And, they were considerably lighter than their wooden counterparts.

While the Americans continued building wooden and composite sailing ships up to the end of the nineteenth century, the Europeans constructed a number of iron ships. In the 1870s, however, a good quality of mild steel became available and there was a major worldwide shift to its use in ship construction. By the end of the 1880s, iron plates were rarely used--a weight-saving of about 15 percent was possible with steel.

In the period between 1882 and 1905, according to Lloyd's Register, literally hundreds of steel sailing ships were built in British shipyards. On the other side of the Atlantic, in American yards, very few steel sailing ships were built. One example is the Astral built in 1900 by Arthur Sewall & Company of Bath, Maine, for Standard Oil to carry case oil in Far East trade. The Astral, as well as her sister ships Acme and Atlas, were of 3,292 register tons with lengths of 332 feet and beams of 45 feet 6 inches. They were four-masted and ship-rigged with double topgallant sails and royals on each mast. They carried crews of 33 men.

In 1910, the Astral was sold to the Alaska Packers Association of San Francisco--the last American firm to use square riggers. Renamed the Star of Zealand, she worked the Alaskan salmon cannery trade until 1929. After several years in layup, she was sold to the Japanese and became the Star of Zealand Maru.

Another alumnus of the Alaska Packers is the Balaclutha, 1,629 tons, built in Glasgow in 1886. Renamed Star of Alaska, she worked the salmon trade until 1930. From 1933, when she was named Pacific Queen, this old vessel spent twenty years as an exhibition ship on the California coast. Finally, in 1954, the San Francisco Maritime Museum Association restored the Balaclutha to her original name and condition. She is now on display at Fisherman's Wharf in San Francisco.

Chapter 3

THE TRANSITION FROM SAIL TO MECHANICAL POWER

The nineteenth century saw the complete conversion of cargo vessels from sail to mechanical propulsion. In 1800, except for canoes, rowboats, poled and drifting rafts and flatboats, and animal-driven canal boats plying the inland waters, all maritime commerce was carried on by wind-powered vessels. Yet, by 1900, the day of the merchant sailing ship had passed, reaching its zenith about mid-century, then fading away. Only a few museum relics and training ships are left to mark the passing of this glorious era.

The transition was a gradual one and was marked by many successes and failures. It began with the development of a realiable heat engine and the concommitant development of heat sources, heat conversion devices, and the many other elements of auxiliary machinery that constitute a marine power plant. The transition also involved the development of mechanical and hydrodynamic devices to convert the reciprocating motion of a heat engine into a rotational motion, and thence into a fluid acceleration to produce a propulsive thrust.

Early Attempts at Steam Propulsion

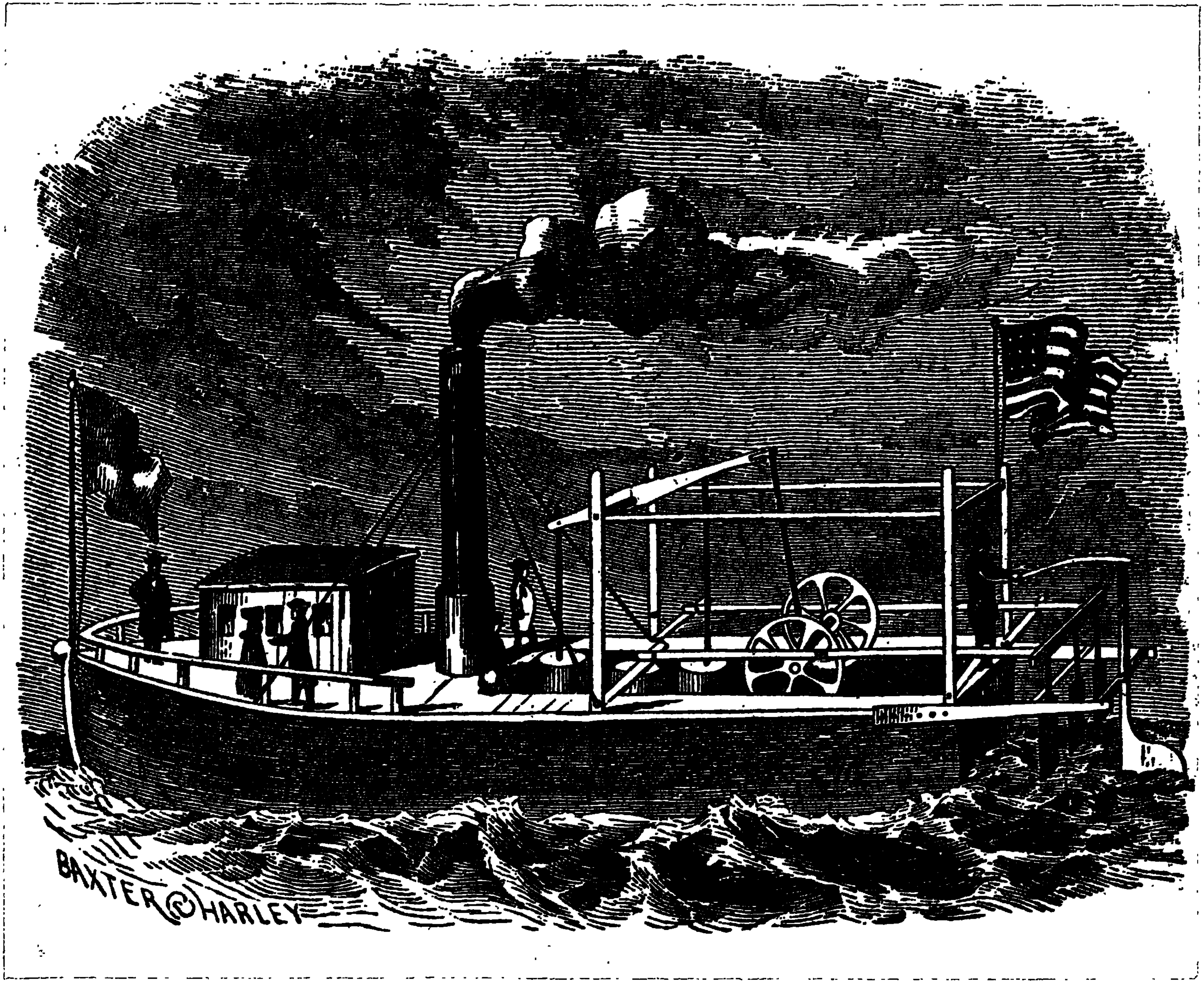
At the close of the eighteenth century, the most important developments leading to the mechanical propulsion of ships were the inventions of a Scottish mechanic, James Watt. He obtained his first steam engine patent in 1769. His disclosure described an auxiliary condenser and an enclosed cylinder, and suggested using oil and tallow for lubrication. His second patent, issued in 1782, covered the expansion engine, the double-acting engine, and the use of a double cylinder. His third patent, obtained in 1784, included such refinements as a parallel-motion locomotive engine and handgear and valves. These inventions, taken together, covered most of the primary components of the modern steam reciprocating engine.

Watt appeared satisfied to let others worry about the maritime application of his engines, and many others did concern themselves with shipboard installation and operation, as well as engine development. The lack of communications and the lack of a good patent system during this period of rapid development gave rise to many conflicting claims of discovery and many hard teelings between inventors in both England and the United States. To assign singular credit to any one inventor for the steamboat is a virtual impossibility. Despite the vitriolic claims and counterclaims traveling back and forth across the Atlantic, the types of mechanically propelled craft which were developed were the products of the ingenuity and tireless energy of many men striving toward a common goal. To gain a true perspective of the progress of propulsion developments during this period, several contributors' stories should be briefly told. The following accounts are primarily those of American inventors.

James Rumsey of Shepardstown, West Virginia, first developed an interest in steam for ship propulsion at the age of 40. By 1784, he had built an 80-foot steamboat of the hydraulic jet propulsion type. He conducted numerous experiments with it in the Potomac River during the ensuing three years and, in 1787, held a public demonstration before several hundred people, including General George Washington. The boat, carrying three tons of cargo, was piloted back and forth on the Potomac for two hours at a speed of three miles per hour. General Washington was so intrigued with Rumsey's demonstration that he encouraged him to go to Philadelphia. There the Rumseian Society, of which Benjamin Franklin was a member, was formed to promote his inventions.

Rumsey applied for a patent in the United States, then, fearing that his invention might be stolen, he destroyed his boat and set sail for England to obtain additional patents and working capital. He turned down a partnership offer from Boulton & Watt, who enjoyed an almost complete monopoly over Britain's supply of engines and boilers, and began construction of the 100-ton steamboat Columbia Maid. In 1792, just before the river trials were conducted, Rumsey died of apoplexy. The boat, operating on the hydraulic-jet principle, had some success and made several trips on the Thames, against wind and tide, at a reported speed of four miles per hour. Rumsey's English patent, granted in 1788, covered the watertube boiler and many fundamental principles of power plant economy, as well as the steamboat itself. His United States patent, issued in 1791, covered a propulsion device which generated thrust from the reaction of a stream of water forced out the boat's stern by steam from a cylinder mounted parallel to the keel.

Nathan Read of Warren, Massachusetts, a 1781 Harvard graduate, initially occupied himself with the design of a light, compact boiler. By 1788, he had completed drawings for what he called his "portable furnace boiler," designed for use in steam carriages and steamboats. Although Read built a steamboat in 1789 and proposed the idea of raising and lowering the paddles to accommodate different ship drafts, his greatest contribution to the field of ship propulsion was his boiler. It was a vertical, multitubular firebox-design which remained in use for many years. Read was granted a patent for his boiler in 1791.


BAXTER © HARLEY

Captain Samuel Morely of Connecticut built a steamboat propelled by a stern paddle wheel. In 1790, his boat made the trip from Hartford to New York City at a speed of five miles per hour. He demonstrated another of his boats a few years later at Philadelphia.

John Fitch, whom many credit as the inventor of the steamboat, was born in East Windsor, Connecticut, in 1743 and at the age of 17 went to sea. At 40, he settled down in Warminster, Pennsylvania, and by 1785 had completed his first model steamboat. The propulsive device was a pair of paddle tracks mounted port and starboard, each carrying light buckets. The buckets were rectangular plates pinned to the moving track and supported by flat-bar backbraces. Finding that the buckets labored so hard underwater, Fitch altered his design to provide six oars on each side of the boat. The oars were linked to the engine flywheel so that they were immersed in the water during the backward stroke, and lifted out of the water for the forward stroke. Three oars on each side of the boat were in the water at all times supplying propulsive thrust.

Fitch's ship's hull was 45 feet long and 12 feet in beam. The vessel made a successful trial on the Delaware River, at Philadelphia, on August 22, 1787. Larger vessels were constructed by Fitch in 1788 and 1790. The 1790 version was run as a passenger boat, at a speed of eight miles per hour, between Philadelphia, Burlington, Trenton, Chester, and Wilmington. The United States patent granted to John Fitch in 1791 covered a propulsion device not used in any of his boats. It described the use of steam to pull water in at the bow and eject it at the stern, very similar to Rumsey's designs.

The last of the eighteenth century inventors to receive an American patent for his work was Colonel John C. Stevens. Stevens was a lawyer, born in New York in 1749, who had taken up residence in Hoboken, New Jersey. He witnessed Fitch's demonstration at Philadelphia in 1787, and for the next 30 years he avidly engaged in steam propulsion research.

In 1789, Stevens petitioned the New York state legislature for the exclusive right to navigate the waters of that state by steam-propelled vessels. He was turned down because the steamboat plans he submitted did not meet the requirements. In 1790, Stevens followed up his petition with a forceful request for laws to protect American inventors; the present patent system of the United States stems from his requests and suggestions. As noted in the accounts of other inventors, the first United States patents for steam propulsion were granted in 1791. Stevens obtained one covering a hydraulic-jet propulsion device similar to the ones proposed by Rumsey and Fitch, and continued with his own work, studied the work of others, and conducted experiments with different propulsion systems.

While these individuals carried on their research, countless arguments arose regarding the claims of the many inventors working on essentially the same devices. The confusing patent legislation in no way helped the situation. There seems to be no doubt that, in spite of the distances which separated the inventors of the day, pirating of ideas was commonplace. One of the most ubiquitous visitors and avid correspondents of the time was Robert Fulton. During the last years of the eighteenth century, Fulton's ideas were germinating; claims of his piracy were to surface after his success several years later.

Despite the arguments which surrounded propulsion development at the close of the eighteenth century, it was a period of great progress. Experiments proved conclusively that a steam-engine-driven propulsion device could move a vessel through the water at an average speed greater than that achieved by animal power or sail. Furthermore, demonstrations showed that such schemes were both practical and of potential commercial advantage.

Prior to 1800 almost every ship propulsion device known today had been either suggested or actually tried in full scale experiments. Of the paddle types, the bow-wheel, stern-wheel, side-wheel, submerged-wheel, and wheels mounted between twin hulls had been used; paddle tracks had been tried; and inventors had at least proposed the feathering and adjustable-draft types of wheels. Engineers had designed screw propellers similar to modern configurations; the Archimedian screw was perhaps the most popular.

Various inventors had built surface propellers and airscrews and had proposed single-screw, twin-screw, and triple-screw installations. The retractable screw and steering screw were not unknown. Many forms of hydraulic jet propulsion were suggested, including jets generated by steam pumps, internal paddles, and exploding gases. Engineers developed various types of gas jets and proposed a variety of locations on the hull for intake and discharge openings. They designed a rotating-blade propeller in the form of a mill drive. They experimented with wind and water power, and also used steam to drive mechanical propulsion systems. Ships had even been propelled by duck-feet, goose-feet, oscillating umbrella cones, and vibrating boards.

Paddle Wheels for Ship Propulsion

Although the last decade of the eighteenth century had seen reasonably successful applications of hydraulic jets and oscillating oars driven by steam engines, the paddle wheel appeared to be the propulsion device most adaptable to the low speed engines of the day. It remained only to improve the engineering and materials of the boiler and engine, and to strengthen the hulls to support large concentrations of weight, before the practical self-propulsion of waterborne vehicles could become a reality.

In England, William Symington concluded that the most logical type of craft, from a commercial standpoint, was a tugboat. He began construction of an engine. It was a horizontal, double-acting engine with a single 22-inch diameter cylinder and a stroke of four feet. The connecting rod and crank coupled the piston directly to the paddle-wheel axis. In 1801, Symington fitted his engine in a small tunnel-stern tugboat, the Charlotte Dundas. Fitted with a bow rudder for easy maneuvering, she moved through the Forth and Clyde Canal on her trial run at a speed of six miles per hour. Towing two other vessels of 70 tons each, she made a speed of slightly more than three miles per hour. She was the first successful steamboat built in England, and probably the first steam tug in operation in the world. Symington's engine, built with crank, connecting rod, and guides, was a remarkable product at this early date, and he could lay claim to being the father of the paddle-wheel engine.

Meanwhile, Robert Fulton went into the steamboat business in earnest. While living in Paris, he built an experimental steamboat, the Nautilus, which was launched in 1803. Fulton proved to be a better marine engineer than naval architect. The hull of his vessel did not have sufficient strength to carry the weight of its machinery. When the engines and boilers were placed aboard, the ship broke in half and sank. By August 1804, he had constructed a new hull, 66 feet long, with a beam of 8 feet. His machinery, having been salvaged in relatively good condition from the bottom of the Seine, was installed in the new hull. But the vessel was quite unsuccessful and made very low speed through the water. Discouraged, Fulton visited Symington in England and rode the Charlotte Dundas. Symington gave him several valuable ideas, which Fulton later used to good advantage.

Fulton's career received its greatest impetus in 1803, when the New York legislature passed an act granting Chanceller Livingston and Robert Fulton the rights and exclusive privilege of navigating all the waters of that state with vessels propelled by fire or steam. To be in effect for 20 years, the act contained the condition that the practicability of driving a 20-ton vessel at four miles per hour, with and against the normal current of the Hudson River, be demonstrated within two years. The termination date of this conditional clause was later extended to April 1807.

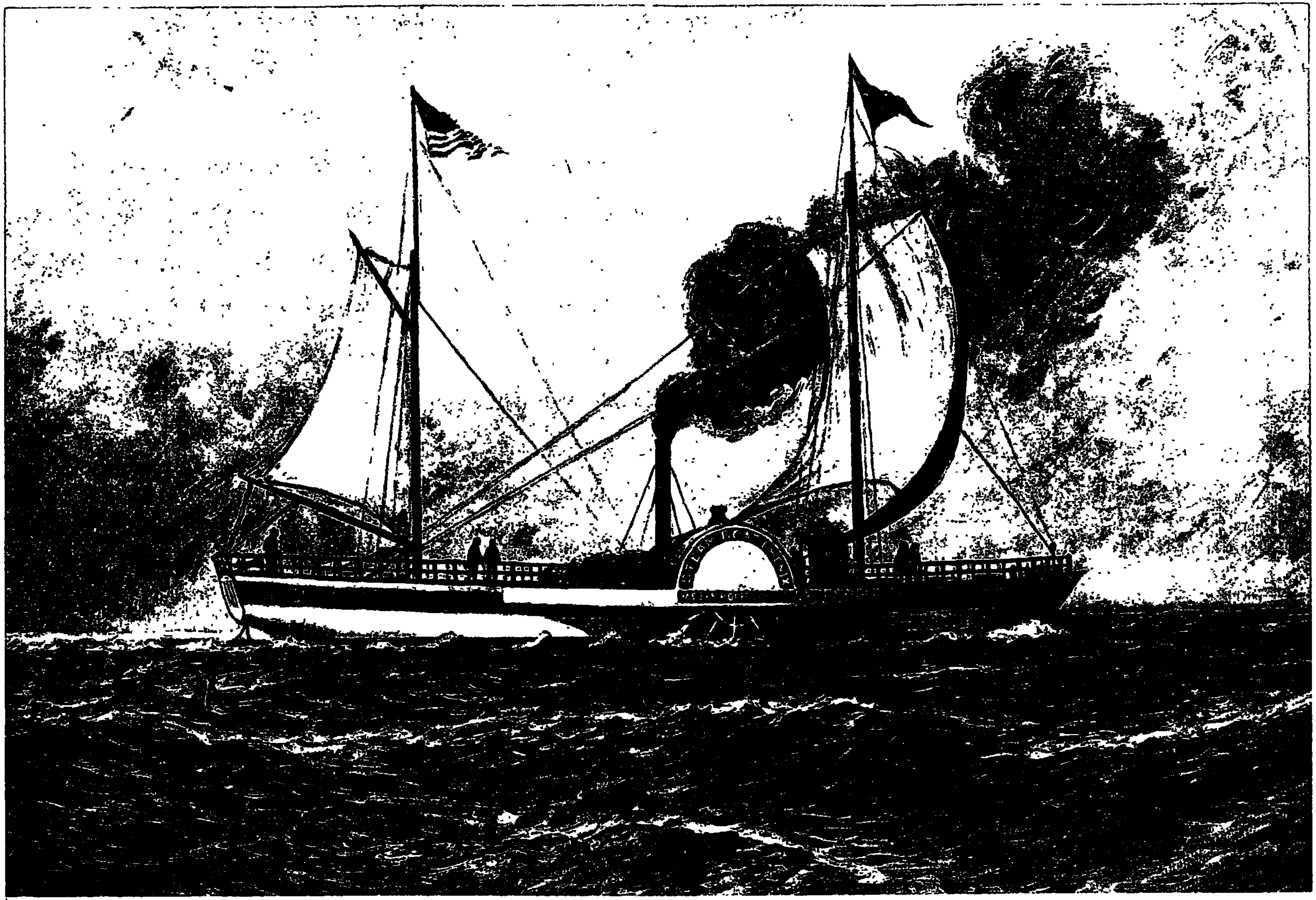
During the same period, Oliver Evans built a boat to ply the waters of the Mississippi. However, by the time the engine arrived in New Orleans to be installed in 1803, the boat had been destroyed in a hurricane. The engine was then diverted for use in a lumber mill, where it performed satisfactorily for a number of years. Undaunted by this setback, Evans continued his experiments, and was probably the first to use the power of steam to drive an amphibious vehicle. In 1805, he built a steam-powered floating dredge, which he named *Oruktor Amphibolis*. Wagon wheels, rigged so that they were turned by the engine, were mounted on this dredge for operation on land. By this method it was propelled across the city of Philadelphia to the Schuylkill River. With the wheels removed, the vehicle was launched. and a paddle wheel fitted to its stern. It then proceeded down the Schuylkill to the Delaware.

In 1786, Evans had become convinced that James Watt was not properly utilizing the inherent energy of steam in his low-pressure engine; he began to experiment with high-pressure steam and its "elastic power." Aside from his brief experience with the *Oruktor Amphibolis*, he concentrated on stationary engines and, in 1802, produced his first small high-pressure steam engine. With a 6-inch bore and an 18-inch stroke, it proved to be a remarkedly sound design. He also developed a high-pressure firetube boiler similar to the later Scotch marine boilers.

Evans became quite successful and, in 1807, he established the Mars Iron Works. Soon his engines were working from Philadelphia to Connecticut and west to Ohio. His last great work was the construction of the engine and boilers for the Fairmount Waterworks in Philadelphia. The engine had a 20-inch bore and 5-foot stroke; it operated with four boilers at 200-pounds-per-square-inch pressure.

In 1805, Colonel John Stevens and his son, Robert L. Stevens, started design work on a side-wheeler to be named the *Phoenix*. Construction was started in 1806, and the ship was operating on the Hudson River in early 1808. The *Phoenix*, 103 feet long, was equipped with paddle boxes and guards and had a well-formed hull. But, in the spring of 1807, a vessel was launched from the yard of Charles Brown on the East Hudson River which was destined to greater fame than the *Phoenix*: Robert Fulton's *Clermont*. The *Clermont* was an oddly constructed boat without a deck, flat bottomed, and with angular lines. She was 140 feet by 16 feet by 7 feet with a 28-inch draft. The *Clermont*, driven by an imported Boulton & Watt engine, started her trial run from New York to Albany on August 7, 1807. Her average speed was five miles per hour. With this successful trial run, Fulton guaranteed his franchise for the exclusive use of the waters of New York state during the next 16 years.

The Hudson River was ideal for developing steam navigation. It connected two major centers of commerce, and yet there was no easy mode of transportation upriver. The high terrain on both sides made winds erratic so that navigation under sail was extremely difficult. No good roads followed its banks to provide reliable overland transport, nor were there paths for mules or oxen to tow barges. The river, however, was deep and straight and had no dangerous tides or currents.



PHOENIX 1808

Built at Hoboken, N. J., wood, tonnage unknown, by John Stevens and his son Robert L. Stevens, the first wholly American built. Prevented by Fulton and Livingston's monopoly from operating on the Hudson River, ran a few trips between New York and New Brunswick, then sent by sea to Philadelphia captained by Moses Rogers accompanied by Robert L. Stevens, the first steam vessel to navigate at sea. Ran between Philadelphia, Trenton and Bordentown. Retired in 1816. Scrapped at Trenton, N. J.

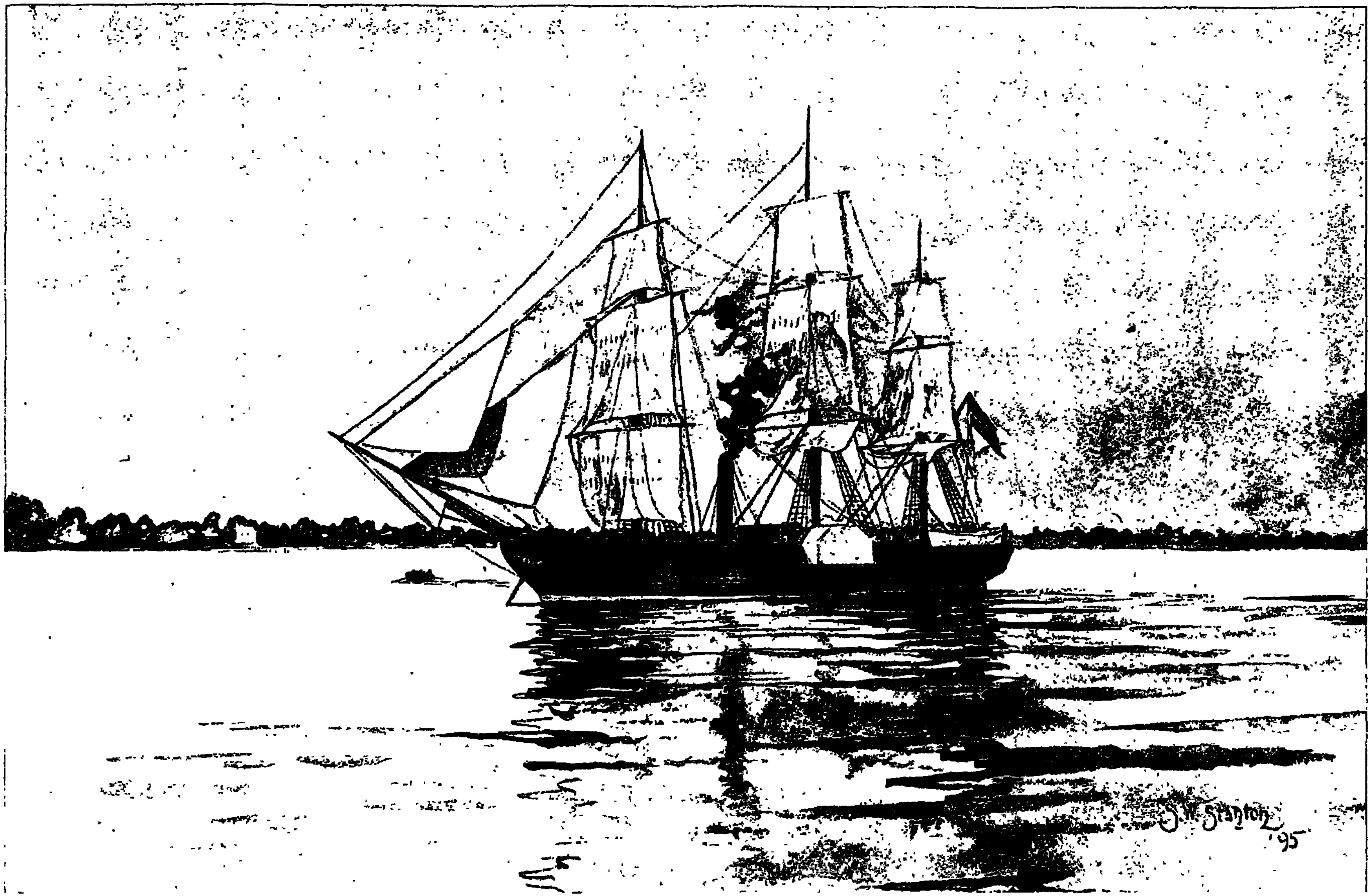
Thus, geography and Fulton's exclusive right to steam navigation combined to make the Clermont the first commercially successful steamboat in the United States.

Stevens, excluded from New York waters by Fulton's franchise, decided to take the Phoenix to Philadelphia. In June 1809, with Robert L. Stevens as engineer, the Phoenix proceeded under steam from New York, around Cape May, into the Delaware River,'and thence to Philadelphia, becoming the first steamboat to make a successful ocean voyage. For many years she operated between Philadelphia and Trenton.

For the next decade, paddle-wheel driven vessels were introduced as means of transport in inland waters throughout the world. In 1809, the Quebec Mercury was launched on the St. Lawrence, followed by the Swiftsure in 1813. The Van der Capellan, built in Batavia in 1810, went into service as a troop transport to India. In 1811, the New Orleans was built in Pittsburgh and went into service on the Mississippi between Natchez and New Orleans. The Comet went into service on the River Clyde in Scotland in 1812. In 1815, a four-horsepower steamboat operated between St. Petersburg and Kronstadt in Russia, and, in 1817, the Massachusetts went into operation in Boston.

Aside from the trip of the Phoenix around the New Jersey coast, the credit for pioneering seagoing paddle-wheel steamers goes to the British. An engineer from London, George Dodd, was the first to investigate the possibilities of this new type of propulsion for ocean travel. In early 1815, Dodd arranged the purchase of the Argyle, a steamboat then operating between Glasgow and Greenock, Scotland. The ship was 79 feet long with a beam of 16 feet. She had a 14-horsepower engine driving 9-foot diameter side-wheels. Dodd renamed her the Thames, and, in May, set sail from Glasgow for Dublin. The crossing was extremely rough and almost ended in disaster when the ship nearly ran aground off Port Patrick. The combined power of steam and sail was needed to keep her off the rocks, but she finally made the crossing to Dublin Bay. There she stayed for a short time for examination of the machinery and for relaxation of the crew.

The Thames then headed for Milford Haven, again in the face of rough seas. The buoyant action of the paddle boxes cut down roll, but created another problem which proved disconcerting to the crew and passengers. As the waves pounded against the side of the vessel, the air in the paddle boxes was compressed and forced out through small openings between the planks--the resulting noise was frightful. From Milford Haven, Dodd ran the Thames to Portsmouth, thence up the Thames River to London. She passed every other boat on the river, much to the amazement of all witnesses. The Thames covered 758 miles, through adverse weather conditions, in five days and two hours—indisputable proof that the paddle-wheeler had a definite place in the seagoing commerce of the day.



SAVANNAH 1819

Built at New York, wood, 320 tons, by Fickett & Crockett for Scarbrough & Co. of Savannah, Ga. Ran one round trip between Savannah, Liverpool, St. Petersburg, Russia, and return to Savannah, often under sail alone. Engines then removed, and ran as sailing packet between Savannah and New York. Ran ashore on Fire Island and went to pieces.

The next seagoing steamer was the Rob Roy built by David Napier, as prolific a contributor to the advancement of steam navigation as was his cousin, Robert Napier. The Rob Roy was a 90-ton vessel with a 30-horsepower steam engine. In 1818, she began regular runs between Greenock and Belfast, establishing the first scheduled seagoing service of steam-powered vessels. She served that route for two winters with great success, then was transferred to cross-channel runs between Dover and Calais.

The United States recaptured the lead in introducing steam at sea with the Savannah, which was the first steam-powered vessel to make a transoceanic crossing. This historic ship was built by Crocker and Fickett of Corlear's Hook, New York, through financing by a group of speculators who hoped to sell her to the tsar of Russia. The Savannah was a 320-ton, ship-rigged sailing packet. Her 90-horsepower inclined engine was placed between decks with the boilers in the lower hold. Her paddle wheels could be collapsed when she was proceeding under sail.

In 1819, Savannah got underway for Europe. The first leg of the voyage was from New York to Savannah, Georgia. It required 7 days, 4 of which were under steam. From Savannah, the ship headed for Liverpool. The passage to St. George's Channel, off the city of Cork, required 18 days, 7 of which were under steam. After a brief stop, the Savannah proceeded to Liverpool. From Liverpool, the Savannah made for Kronstadt and St. Petersburg, via Copenhagen. Although she aroused much interest, the anticipated sale to the tsar was not consummated, and her captain, Moses Rogers, gave orders to head for home. She arrived in Savannah 22 days later after a passage under sail alone.

Because of too much rigging, a heavy and low powered engine, rather frail paddles, and insufficient fuel-storage space, the Savannah was a commercial failure as a steam vessel. Her owners, after losing between $50,000 and $60,000 on the transaction, had her machinery removed, and she was put in service as a packet between Savannah and New York. She later went aground on Long Island, broke up, and sank. Although a failure from the commercial standpoint, the Savannah made a significant contribution to maritime history. Her voyage demonstrated the feasibility of transatlantic steam navigation. But thirteen years would pass before another crossing by a steam-powered vessel was made.

Although no transatlantic crossings were tried, steam-powered vessels were not lacking in shorter seagoing runs. The 700-ton Robert Fulton went into service between New York, Charleston, Cuba, and New Orleans in 1819 and plied this trade successfully for three years. In the same year steamboats were introduced to the Great Lakes as

Walk-in-the-Water went into service on Lake Erie. In 1827, a steamboat started operating on Lake Michigan.

The Robert Fulton was the first vessel to be designed as an ocean-going steamship. Her dimensions were 158 feet by 33 feet by 15 feet and she drew 10 feet of water. Both engine and boiler were constructed in the United States by James P. Allaire, a mechanic trained by Robert Fulton. The Robert Fulton was later sold to Brazil. With her boiler and engine removed, she was said to have been the fastest sailing corvette in the Brazilian Navy.

American progress in steam propulsion was slow relative to the British until the 1840s. However, in 1846, legislation was passed by Congress awarding lucrative mail contracts to steamship companies willing to build ships that could be used as naval auxiliaries. Three steamship companies were established: the Collins Line, which received a transatlantic mail contract; the Law Line, awarded the contract for the run from New York to the Isthmus of Panama; and the Pacific Mail Steamship Company, contracted to carry the mails from the Isthmus to California and Oregon.

Just as the first vessels built under these contracts went into operation, gold was discovered in California. One of these vessels, the Tennessee, built by William H. Webb in 1848, was diverted from the New York, Charleston, Savannah trade to the Pacific where she ran until stranded in 1853. The Tennessee was a typical coastwise steamer of the time. She had relatively fine lines, no deadrise, and a wooden hull strapped with iron for internal structural strength and engine support. Her three masts carried a minimum of canvas which was used mainly for roll stabilization. Speed was limited to 10 knots when driven by her side paddle wheels.

The speed limitation on vessels of this era was based primarily upon the amount of coal they could carry. The engines operated at steam pressures of about 15 pounds per square inch. If they used their coal at a more rapid rate they could attain higher speeds but the miles per ton of coal were reduced. The boilers used sea water and jet condensers were employed. Because higher temperatures and pressures resulted in an insoluble salt deposit in the boilers it was not feasible at that time to use the 120-pounds-per-square-inch pressure being used in the fresh water vessels on the Great Lakes and inland waterways. James Watt's surface condenser and recirculating steam systems were not employed in American vessels until the time of the Civil War.

In the wake of the Tennessee, new steamship lines came into being as rapidly as old vessels could be accepted and new ones built. Ships plied the East and West coasts to fill the enormous demand for freight and passenger service, and the Panama railroad, running across the Isthmus, did a roaring business.

From 1850 to the beginning of the Civil War, the American maritime industry reached a record high point. American clipper ships were travelling all over the world breaking one record after another. In 1858, 76 percent of American exports and imports were carried in American bottoms. The Atlantic speed record of an average of 13.97 knots westbound and 13.50 knots eastbound was established by Collins Line ships running between Liverpool and New York. American shipyards were building both steamships and sailing ships for foreign countries including warships for Russia, Italy, Mexico, Japan, and Germany.

The Screw Propeller

Comes to the Fore

One engineer who experimented in a forthright and logical manner with screw propulsion was the Phoenix's owner, Colonel John C. Stevens. Colonel Stevens fortunately was endowed with adequate financial means, a keen engineering mind, and a great deal of patience. In 1804, Stevens built a small boat, 25 feet long, in which he installed a rotary steam engine directly coupled to a screw propeller. His initial trials on the Hudson River showed the engine to be unsatisfactory. After replacing the engine with a type resembling James Watt's, he was able to attain a cruising speed of four miles per hour, with occasional spurts of speed up to eight miles per hour.

Stevens' propeller had four blades and was built up of forgings to which iron plates were riveted. The blades were adjustable, and Stevens ran trials on the Hudson for about two weeks with a variety of pitch settings on the propeller. Apparently he considered the performance unsuccessful and redirected his efforts to paddle-wheel propulsion.

The difficulties which Stevens encountered were typical of those met by the early advocates of screw propulsion. The engines he tried were of very low rotational speed. Turning at these speeds, his crude propeller could attain only a small fraction of its potential thrust since the efficiency of such a propeller is related to the product of the diameter and the rotational speed. To Stevens, the test results indicated that the paddle wheel was a much more promising propulsive device for use with the engines available at the time. It is regrettable that he did not continue to devote his abilities to the development of higher-speed engines, rather than entering into what proved to be a fruitless competition with Fulton in the field of paddle-wheel propulsion. Stevens did, however, continue his interest in the screw propeller and claimed that it would eventually become the primary propulsion device for ships.

Credit for the development of the screw propeller in the United States belongs to John Ericsson. He was born in the province of Vermland in Sweden on July 31, 1803. A talented child with a mechanical bent, he was producing his own designs and models at the age of 10. These attracted the attention of Count Platen, who influenced the Corps of Mechanical Engineers to accept Ericsson as a cadet. In that Corps, Ericsson served as a leveler and draftsman during the construction of the Canal of Gotha. In 1826, he constructed an air engine which he took to England to develop. By the time he turned his attention to the screw propeller, he had already designed and built a steam boiler, a railway locomotive, steam fire engines, and a caloric engine.

Ericsson obtained his first propeller patent in England in 1836 and built a model boat, approximately three feet long, on which to test the device. The model tests, in a circular London bath, were so successful that he built a 45-foot boat, equipped with a pair of contra-rotating propellers; Ericsson named the boat Francis B. Ogden. Free running, the Ogden was said to have attained a speed of 10 miles per hour. Ericsson saw in his propellers tremendous military potential. He approached the British Admiralty with the proposition of building larger, screw-propelled vessels but received little consideration. Discouraged with the reception of his invention in England, Ericsson moved to the United States. But before doing so, he built the passenger boat Enterprise for John Thomas Woodhouse and the Robert F. Stockton for Captain Robert F. Stockton, USN, then on duty in London. The Stockton was taken, under sail, to the United States in 1839. In 1840, she was sold to the Delaware and Raritan Canal Company and renamed New Jersey. She saw service for nearly thirty years as a steam tug on the Delaware and the Schuylkill rivers.

Ericsson arrived in the United States in 1840. He soon fitted his bladed-wheel screw to government ships, the revenue cutters Legare, Jefferson, and Spencer; and, due largely to his efforts, 41 screw-propelled American merchant ships were operating by 1843. The London Engineer of May 11, 1866 said: "It is worthy of notice that Ericsson applied his propeller to upwards of sixty vessels in America before any other form of propeller was adopted, nor is it less worthy of remark that the adoption of his propeller proved a great commercial success from the start, many of the original vessels being now, after fifteen years of service, in good working condition."

The first screw-propelled vessel in the United States Navy was the Princeton, built in 1843, and it was claimed that she was the first screw-propelled military vessel ever built. The Princeton, designed and constructed by Ericsson, was 164 feet long, had a beam of 30 feet 6 inches, a depth of 21 feet, a mean draft of 17 feet, and a displacement of 673 tons. In October 1843, the Princeton was pitted against the paddle-wheeler Great Western at New York, and was victorious in the contest. Ericsson also contructed the 2,000-ton, "caloric" ship Ericsson, which was driven by a heated compressed-air engine of four cylinders, each 168 inches in diameter.

Whether he wrote of the same Ericsson is unconfirmed, but Bennet Woodcroft in his "Sketch of the Origin and Progress of Steam Navigation," 1848, noted the fact that "the introduction of the first screw steamer, the Ericsson, between Philadelphia and Baltimore by the inland route, via the Chesapeake and Delaware Canal, completely annihilated as a profitable speculation one of the greatest works in the country, the Philadelphia and Baltimore Railroad." The railroad cut its fare in half and, although the government protected railroad passenger service by a prohibitive toll on ship passengers, the railroad lost its freight business to the screw-propeller line. This was perhaps one of the earliest contests in the running battle between the railroads and inland-waterway carriers that has continued to this day.

Probably the greatest service rendered by John Ericsson to his adopted country was the construction of the Monitor. Under the sponsorship of Donald McKay, Charles Ellet, and C. S. Bushnell, Ericsson built a model of the ironclad and submitted it to President Lincoln who immediately sanctioned construction of a full-sized ship. At a cost of $275,000, the Monitor was built and delivered in 100 days with the resulting disastrous effects on the naval ambitions of the Confederacy.

Despite these successes, there were still many problems in the design, construction, and operation of screw-propelled ships. Wooden-hulled ships were subjected to heavy vibration; iron hulls were needed to resist the vibratory forces. With shaft and machinery below the waterline, stuffing boxes to prevent leakage without damaging the rotating shaft had to be developed. Thrust bearings were required to transmit the forward force exerted by the propeller to the hull. Higher-speed engines had to be developed to realize the inherent efficiency of the screw; and techniques for casting and machining strong, tough metals were needed.

The development of screw-propelled vessels in the United States by Ericsson took advantage of more advanced marine engineering techniques than those developed in England. From the outset, Ericsson used direct-drive, high-speed engines, whereas the British employed the slow-speed engines used for paddle steamers and coupled them to the propeller shaft through speed-increasing gears. But even Ericsson's engines did not exploit the screw propeller to the maximum extent possible and, with the attention of the Americans diverted by the Civil War, the British gradually forged ahead in the international contest for primacy at sea.

As noted earlier, Ericsson's first propellers were what might be called "bladed wheels." These were built up of one set of pitched blades extending from the hub to an inner ring and another, greater numbered set of pitched blades extending from the inner ring to the outer ring around the circumference of the propeller. The design had many distinct advantages. It was possible to obtain the increased thrust of a large number of blades (eight blades between the outer pair of rings) in a small diameter without cluttering up the area adjacent to the hub. Yet, both the inner and outer elements supplied propulsive thrust. The wheel design was inherently strong without unnecessary material interfering with its basic action. He also used two screws on concentric shafts rotating in opposite directions; these are now called contra-rotating propellers and, although used primarily on torpedoes as a torque cancelling device, they have been seriously considered for ship propulsion because of their inherently higher efficiency.

The British developments in screw propulsion stemmed primarily from the Archimedian screw-type developed by Francis Petit Smith in 1836. It evolved through a number of convolutions of multiple threads down to partial convolutions of two, three, or four threads. By 1843, the HMS Rattler had become the first military ship fitted with a two-bladed screw; the blades very much resembled a modern, cast, screw propeller. There seems to be no record as to whether Ericsson's designs followed a similar trend or whether he continued with his original bladed-wheel concept. In any event, the bladed wheel disappeared from the scene, and cast propellers more closely resembling the blade shape originated by Colonel Stevens were used on American ships during and after the Civil War.

In addition to the Civil War, there was another, more subtle, reason for Britain achieving maritime prominence. United States shipyards continued to build wooden ships and then composite ships long after iron and steel were adopted in England and Europe. Enormous amounts of timber were available in America, as was the requisite skilled labor--built up over 200 years of wood shipbuilding. American builders were ingenious when it came to the use of strapping, tie rods, and large wooden trusses that could get around the lack of strength inherent in wood construction.

This wealth of materials and talent eventually worked to the detriment of the American marine industry. Because of the tendency to stay with wooden construction, paddle-wheel propulsion was used to avoid propeller vibration problems. When the inevitable switch was made to steel construction and screw propellers, the Americans were far behind the British. The United States led the way in the 1850s but its position of leadership eroded away in the 1860s.

Nevertheless, as a seagoing propulsion device, the paddle wheel was doomed to ultimate replacement as soon as adequate driving machinery became available for screw propellers. Side-wheelers, when the ship rolled in a seaway, experienced immersions ranging from zero dip to well above the axle. In a never ending sequence, the thrust of each wheel would cycle up and down to the point where the mean efficiency was far below what the paddle wheel could achieve in calm water. Not only did this result in an inefficient form of propulsion, but the stresses on the paddle-wheel structure and the machinery were enormous. Breakdowns were frequent, and many of these ships had to make their way home under sail with broken paddles or with cracked crankshafts.

On inland waterways, the paddle wheel was initially better designed to cope with the operating environment than the screw propeller. Increased depths and waterway improvements later changed conditions to the point where the screw could be used effectively. In the deeper waterways, screw propellers came into use about the same time they replaced paddle wheels at sea. For example, the Union fleet, under screw propulsion, made its way up to Vicksburg on the Mississippi during the Civil War. Here, the underwater screw had a military advantage, being less subject to damage by gunfire than the exposed paddle wheel. However, the use of paddle wheels on the inland waterways continued well into the twentieth century because of their operational capabilities in shallow water and their inherent efficiency when the dip of the paddles could be precisely controlled in calm water.

At the time the screw propeller was replacing the paddle wheel, the science of naval architecture was also developing. The days of hand-carved hull models were passing and greater thought was being given to the difference between a ship propelled by sail and one using a screw propeller. For a century, little attention had been paid to the words of the Swedish naval architect, Frederick Henry de Chapman in "A Treatise on Ship-Building," 1755; he concluded that the art of shipbuilding could never be perfected until we had attained a knowledge both of the theory and the practice of ship design.

With the formation in 1889 of the American Society of Naval Engineers and, in 1893, the Society of Naval Architects and Marine Engineers, American publication of papers on the theory and practice of shipbuilding and of ship design was begun. Other publications on these subjects also began to appear.

Comprehensive treatises on propeller design were published by Carl Busley in 1885, David W. Taylor in 1893, J. Pollard and A. Dudebout in 1894, S. W. Barnaby in 1900, G. S. Baker in 1905, H. Johow and E. Foerster in 1928, G. Kempf and E. Roerster in 1932, G. S. Baker in 1933, and Karl E. Schoenherr in 1939. The most complete work on the subject is included in the first two volumes of Hydrodynamics in Ship Design by Captain Harold E. Saunders, USN (Ret.), published in 1957.

Probably more theoretical work has been done on propellers than on any other phase of ship design. The transition from total empiricism to mathematical design is still in process; but, with the knowledge which now exists, the design of a good propeller is much more of a science than an art.

Model Testing

Supplementing the theoretical work on propeller design was the development of techniques for testing scale models of ships and propellers. William Froude laid the foundation of the science of scale-model resistance measurement; his Law of Comparison provided a reliable means of predicting full-scale resistance from model tests. In 1874, Froude built the first towing tank at Torquay, England. He proved his scaling law theories by conducting model and full-scale resistance experiments on the Greyhound. The work of Osbourne Reynolds on frictional resistance, published in 1883, furthered the scientific base of the model-testing technique.

The shipbuilding industry quickly grasped the importance of this novel method of determining a ship's performance before construction. Experiment stations were built in many cities around the world: Dumbarton (1883), Haslar (1886), Spezia (1889), Ubigau (1892), St. Petersburg (1893), Washington (1898), Bremerhaven (1900), Ann Arbor (1905), Hamburg (1908), Nagasaki (1908), Tokyo (1910), Teddington (1911), Vienna (1919), Langley Field (1929), Rome (1930), Ottawa (1930), Wageningen (1932), Newport News (1933), Hoboken (1935), Carderock (1938), Glen Cove (1948), Cambridge (1951), Berkeley (1955), and many more in recent years.

Early in the history of model testing, self-propulsion of models was introduced to provide additional information on the overall performance of new ship designs. Testing self-propelled scale models of ships is considerably more complicated than conducting resistance tests on the hull alone. It requires individual tests of the propellers and of the hull, and then a test of the two combined. These tests can be made in a circulating water tunnel, but, generally, they are run in the towing basin.

Model testing has provided the naval architect with a powerful tool to prove out his designs at a relatively minor expense compared with the inordinate cost of full-scale construction and optimization by trial and error. This applies both to seagoing ships and inland waterway transportation system development where not only the ship but the waterway too can be modeled. Because these model tests are of such great importance to the maritime industry they are dealt with in some detail herein.

Testing a propeller requires an open water condition. The water entering the propeller must be calm and move at a constant velocity across the entire propeller disc area. The vehicle employed for carrying the propeller is usually a boat-shaped hull which is towed under the towing carriage. Instead of being at the stern of the hull, the propeller is at the forward end of a long shaft which protrudes from the bow. Because of this positioning, the flow around the hull does not influence the propeller.

The propeller shaft is driven by an electric motor contained within the hull. The motor is mounted in a system of balances called torque and thrust dynamometers. The torque dynamometer measures the torque reaction of the motor to the torque of the propeller. The thrust dynamometer measures the axial force exerted along the shaft line as the propeller pulls the boat through the water. A tachometer measures propeller revolutions per minute (RPM). During the propeller test, the hull is towed through the water by the towing carriage at a number of different speeds. For each speed a series of propeller RPMs is used. In each combination of RPM and speed, the torque, thrust, RPM, and speed are accurately measured.

Before the propeller can be installed in the hull model of the ship, a resistance test of the hull alone must be run. The model is towed at different speeds and the force required to pull the model through the water at each speed is recorded. From the resulting speed-resistance information, the effective horsepower of the full-scale ship can be calculated. This power, or EHP, is that required to move the hull through the water, without considering the propeller or the machinery system. After the resistance test, the hull model is equipped with the same type of torque and thrust dynamometers used for the propeller open-water tests and the model propeller or propellers are fitted in their proper positions at the stern of the hull model. Although self-propelled models are equipped to move themselves through the water just as the full-scale ship would, they must be guided and supplied with electric power from an external source.

The towing carriage meets these needs. It moves at a carefully controlled speed along the basin so that the model speed is precisely known and serves to guide the model in a straight line throughout each run. Also, the carriage supplies power for the propulsion motors of the model and provides a platform for the operators to ride on so that the dynamometers and tachometer may be read continuously throughout the run.

The conversion of the self-propelled-model test results to full-scale projections is a complex procedure. The calculations result primarily in the prediction of the shaft horsepower and RPM of the full-scale propeller as a function of ship speed through the water. Shaft horsepower (SHP) is that power which must be delivered to the propeller itself, not including any of the power losses from the friction in the stern tube and stuffing boxes, or the power losses in gears and other mechanical equipment.

Improvements in Propulsion Machinery

The influence of various developments in boilers, condensers, and propulsion machinery on the development of ships both in the United States and abroad has already been noted. The use of some propulsion devices was held up for many years due to lack of suitable powering machinery. In other cases, propulsion devices have been invented to take advantage of the latest trends in machinery design.

Probably the most notable example of this interrelationship was the capitulation of Colonel John Stevens in the opening years of the nineteenth century. His work on the screw propeller was curtailed because the engines of his day did not rotate fast enough to demonstrate its superiority. He then shifted into competition with Robert Fulton, using paddle wheels for propulsion. The screw propeller did not make significant inroads for fifty years.

The earliest paddle engines turned so slowly that their revolutions could be counted with an hour-glass. The side-lever engine, used from 1812 to 1854 had an operating steam pressure which increased over the years from about 5 pounds per square inch to 25 pounds per square inch, with a corresponding increase in horsepower and a slight increase in RPM. But the tremendous size of the oscillating components, relative to the output power, prevented further enlargement of these engines to meet the propulsive-power demands.

Starting about 1835, the steeple engine came into general use aboard inland-waterway vessels. These engines were compact and could develop greater power. Working pressures ranged from 25 to 155 pounds per square inch. Engine requirements differed between boats which plied the inland rivers and those which crossed the ocean. The inland riverboat had a broad beam and was seldom subjected to heavy seas, giving it ample static stability and requiring a minimum of engine protection. For this service, the steeple engine was quite satisfactory--the boats could take a heavy engine with a high center of gravity.

For the seagoing ships, stability was a major factor. In heavy seas, an engine with a lower center of gravity was necessary to maintain ship stability. The side-lever engine was the first type to fill this need and was followed shortly by the oscillating and diagonal types. Oscillating engines, with working pressures of 30 to 150 pounds per square inch, were first installed aboard ship in 1825 and were phased out of marine service about 1880. Diagonal engines, operating at pressures from 50 to 220 pounds per square inch, were first installed about 1844 and continued in use into the twentieth century.

A major impediment to progress in marine engines was the reluctance to employ the knowledge and hardware available in steam condensation systems. Prior to 1860, jet condensers were used on both seagoing and inland waterway vessels to lower the temperature of the engine exhaust steam in order to get the maximum power out of the heat energy in the steam. A jet condenser simply mixes the exhaust steam with cooling water; the combination is pumped overboard.

This process required a continuous supply of new water to the boilers to make up for the discharged condensate. The required water was obtained from the surrounding ocean or river. However, seawater fed directly into the boilers, when brought to a boil, deposits various types of salts on the boiler internals, steam piping system, and in the engine cylinders. As the temperature, and thus the pressure, of the steam delivered by the boiler to the engine was increased, the salt deposits built up more rapidly. Thus, it was necessary to keep the pressures low on seagoing ships. These lower pressures required larger and more massive reciprocating parts and resulted in low operating efficiency and high fuel consumption. The salt-deposit problem did not affect vessels operating in fresh water and advances in marine engine development were more rapid on the inland waterways and on the Great Lakes, where higher temperatures and pressures could be used.

An important advance was made about 1835 when the surface condenser, originally invented by James Watt, was tried in several seagoing ship installations. In a surface condenser, the cooling water passes through tubes around which the exhaust steam is directed, the transfer of heat from the steam to the water being made through the tube wall. As the steam condenses, it collects at the bottom of the shell and is drained off by a condensate pump. The condensate can then be recycled into the boiler as feedwater so that the entire feed system can utilize fresh water again and again. It does not mix with the salt-water cooling system. The seawater is taken in through an intake sea chest, pumped through the condenser tubes, and then flows out through a discharge sea chest.

In early steam reciprocating engines, tallow was used freely as an internal lubricant. When surface condensers were introduced, problems developed as the tallow recycled through the system, clogging piping, condensate, and feedwater pump. It was not until about 1860 that surface condensers came into general use at sea.

Up to that time, the principal materials available for construction of machinery were cast and wrought iron, whose characteristics set the limits to which designers could work. Between 1860 and 1880 came the development of the Bessemer and open-hearth processes of steel making. The availability and cheapness of the improved materials permitted a steady growth in steam pressures and permissible stresses.

A typical 1860 installation in a 225-foot vessel consisted of a single-expansion, vertical, single-cylinder engine. The piston was 60 inches in diameter, with a 60-inch stroke, driving a four-bladed propeller 14 feet 5 inches in diameter. Succeeding increases in efficiency and speed were attained by use of double- and triple-expansion engines of two, three, and four cylinders. Condensers were improved to obtain greater vacuum, and multiple passes of both fire and steam were utilized to increase boiler efficiency. Early forms of the Scotch boiler came into use. In the transition from single-expansion engines (using 20 pounds steam pressure with jet condensers) to compound engines (using 60 pounds with surface condensers), coal consumption dropped from about four pounds per indicated horsepower-hour to two pounds or less. This advance in economy enabled the steamship to compete successfully with the sailing cargo ship, even on the longest voyages.

In Britain, in 1897, Sir Charles Parsons demonstrated one of the most important marine engineering developments--the steam turbine. The *Turbina*, a 100-foot launch with a displacement of only 44 tons, was fitted with three direct-drive Parsons turbines driving three shafts with a total power of 2,000 horses. In the *Turbina*, the problem of low engine-to-propeller speed ratio was inverted. The minimum speed of Parson's turbines was 2,000 revolutions per minute at maximum power output. To absorb this power, Parsons installed three 3-bladed propellers on each shaft. With its nine propellers, the *Turbina* obtained a speed of 34 knots.

Parsons had solved his problem of excessive engine-shaft speed. He made a further contribution to the science of marine engineering by installing the first marine reduction gear in the *Vespasian* in 1910. This marriage of the screw propeller to the steam turbine, through the medium of a reduction gear, launched a new era in ship propulsion. This combination continues in use today, powering the largest vessels in the world.

Other types of marine power plants are used advantageously in a large number of modern vessels. One of the most important of these is the diesel engine. Rudolph Diesel, in 1892, patented the internal-combustion cycle that now bears his name. After four years of painstaking development, he produced a workable engine in 1897. The first marine diesel installation was placed in a French canalboat in 1902. The Vulcanus, a 1,200-deadweight-ton Dutch tanker, was fitted with a diesel engine in 1910 to become the first seagoing motorship. More and more diesel engines were installed over the ensuing years and they became an acceptable alternative to the turbine for marine propulsion.

Steam turbine powering systems gained an additional advantage in 1920 when the change from coal to oil as a fuel began. Although oil was more expensive, it could be loaded aboard more rapidly; it could be stored in otherwise unused inaccessible places; and it was easier to move from bunkers to boiler. Stoking was eliminated and, with oil, the flow to the furnace could be better controlled. The problem of ash disposal was eliminated and cruising ranges could be considerably extended.

Another type of propulsion machinery plant which has had an influence on ship design is the gas turbine. Although the gas turbine was suggested by Leonardo da Vinci, metallurgical developments have only recently made a practical turbine possible.

The first United States gas-turbine merchant ship was the John Sargent, a converted Liberty Ship of 6,000 horsepower. Since reversing gears in large ships are impractical, the John Sargent was fitted with a controllable-pitch propeller for both maneuvering and reversing. This ship went into service in the summer of 1956; the operation of both the gas turbine and the controllable-pitch propeller were entirely satisfactory. The first in the Maritime Administration's Liberty Ship conversion program, the John Sargent was followed by the William Patterson. The Patterson, also driven by a gas turbine, utilized a free-piston to provide air to the turbine. Gas turbines have proven to be efficient and reliable power plants for marine propulsion in both large and small vessels.

The most notable and exciting development in marine propulsion machinery in the twentieth century has been nuclear propulsion. The first atomic reactor for ship propulsion stemmed from a Manhattan District project designated Daniels Power Pile. The goal was to develop a small industrial reactor. Navy representatives and others working on this project were intrigued with the possibilities of such an indefatigable heat source. When, in 1946, Dr. A. M. Weinberg of Oak Ridge proposed a high-pressure, water-cooled reactor as a power unit for marine use, the idea was received enthusiastically.

In December 1947, the Navy requested the Atomic Energy Commission to design and construct a reactor for a submarine. While the reactor was under construction, the Electric Boat Division of General Dynamics Corporation studied the many problems of installing a radioactive, steam power plant in a submarine. Although the reactor is, in essence, only a source of heat for the boiler that drives a conventional steam-turbine propulsion plant, an extensive array of problems had to be overcome. The keel of the first boat, the Nautilus, was laid in Groton, Connecticut in June 1952. As the Nautilus slid down the ways in January 1954, a new era of submarine warfare was launched. Her amazing performance and underwater endurance engendered a complete revolution in the strategy and tactics of battle beneath the seas.

Nuclear power is also making headway in the surface fleets of the world. In the United States, nuclear-powered cruisers and aircraft carriers are in routine operation. Other navies also have nuclear-powered submarines and surface ships. Although now more expensive than the conventional marine propulsion plant, nuclear propulsion promises to extend the range of naval surface ships and improve the flexibility of the fleet as it reduces warship dependence on slower refueling ships and on advanced base bunkering stations.

At the present time, neither a strategic, nor an economic rationale exists for extending nuclear power to merchant shipping. Not only must the initial investment and the high cost of fuel be considered, but the availability and cost of the highly trained personnel required to run such a power plant must be added to the operational planning and expenses.

Nevertheless, the United States gambled on a future reduction in the first cost and operational costs of nuclear power for merchant ships. The NS Savannah, launched at the New York Shipbuilding Corporation yard in Camden, New Jersey, in July 1959, was the world's first nuclear-powered merchant ship. From her first few years of operation, it was possible to determine many of the economic factors involved in using nuclear propulsion for carrying cargo and passengers across the seas.

With the recent reductions in the size of nuclear cores and containment vessels, the initial cost of a nuclear plant plus the fuel cost during the life of the ship is less than the cost of a comparable oil-fired plant. But experience with the Savannah has shown that other costs enter the equation and tip the economic balance in favor of the conventional oil-fired steam plant for merchant ships.

These other costs include excessively high insurance premiums, an expensive standby tug service, crew training costs, and a home base with facilities for refueling and handling radioactive elements. In the future, some of these excessive costs may be lowered when the inherent safety of the nuclear plant is more widely accepted. And with wider acceptance, other costs can be brought down if they are distributed over a large number of nuclear-powered ships. Nuclear power may eventually assume an important role in the merchant fleets of the world.

The selection of the proper power plant to drive a screw propeller is dependent on many factors. The multicylinder steam reciprocating-engine, the most universally used plant until 1910, still has many advantages. It is exceptionally controllable and can be reversed with ease; its most efficient speed-power range is in line with that of the screw propeller, particularly the large propellers used on single-screw ships; it is simple to operate and maintain. Its disadvantages are limitation of maximum power, lack of efficiency, and excessive weight per horsepower.

The steam turbine delivers high power efficiently. Nevertheless, its most efficient speed is far in excess of normal propeller speeds, thus requiring reduction gears. It is non-reversible unless a reversing turbine is added, which engenders a loss of efficiency. Yet, it can utilize high-pressure, high-temperature steam to the utmost advantage, and can also be designed to use low-pressure steam.

The diesel engine is both easily controllable and directly reversible. It occupies only a small space and is very efficient, but it requires a higher-quality fuel and more lubricating oils than a steam plant. The diesel is a heavy engine and is considerably more expensive than a steam plant of comparable power. Its practical use for many years was generally limited to vessels of less than 3,000 horsepower; however, in the last decade this maximum power level has been increasing. And, since it is primarily a constant-torque machine, the propeller must be carefully designed to match its characteristics most efficiently to those of the engine.

Turbo-electric and diesel-electric drives are also highly advantageous for some special installations. Although higher in initial cost and slightly less efficient than geared or direct drives, they have the advantage of ease of control and an efficient matching of speed-power characteristics with those of the screw propeller.

Because no one power plant can meet the optimum requirements for all marine installations, development has continued in all types. Engine power and efficiency have been increased while weight and maintenance requirements have been reduced. Automatic controls have been devised to reduce operating-personnel requirements, and unmanned engine rooms are now used on many merchant ships.

Chapter 4

SHIPS IN COASTWISE AND OVERSEAS COMMERCE

FROM THE CIVIL WAR TO WORLD WAR II

The Civil War had a disastrous effect on American shipbuilding, but, in spite of the losses of ships, men, and technological development, it was advantageous in one respect. The ironclad warships produced during that conflict stimulated the development of techniques for rolling iron plates, tools and fasteners for working and connecting them, and a work force with experience in using this new shipbuilding material.

Some shipyards that had dominated wooden shipbuilding closed their doors when iron ships replaced wooden ones, but others converted, and new yards were started to build iron ships only. William Cramp and Sons Ship and Engine Building Company, in Philadelphia, which had built wooden ships prior to 1870, converted completely to iron ship production, as did Harlan and Hollingsworth in Wilmington. John Roach's Delaware Iron Shipbuilding and Engine Works, also in Philadelphia, came into being in 1871.

These Delaware River yards became the principal source of iron seagoing ships for the United States merchant marine. At first, they imported engines from Britain, but began building their own after sending representatives to England and Scotland to acquire the most recent technology.

There were various attempts after the Civil War to organize a new transatlantic steamship line. Finally, in 1871, the Pennsylvania Railroad formed the American Steamship Company, which ordered four 3,100 ton ships from Cramp. The ships, Pennsylvania, Ohio, Indiana, and Illinois, each 341 feet long, had compound engines that developed 2,000 horsepower. Each had a single-screw propeller and could make an average speed of 13 knots and carry 876 passengers and 1,740 tons of cargo. For a number of years they were the only steamships flying the American flag in the transatlantic trade.

Pacific Coast Commerce Prior to World War I

The Civil War had far less effect on the development of commerce between the Atlantic and Pacific coasts than it did on the transatlantic trade. The Pacific Mail Steamship Company sent its first steamship, the California, a wooden side-wheeler of 1,050 tons, from New York to San Francisco via the Straits of Magellan and Panama. Making the trip from New York to San Francisco in 149 days, she arrived in February 1849, having picked up 500 passengers at Panama for the last leg of the trip.

The California was soon followed by the sister ships Oregon and Panama and a monthly service was started between the Isthmus of Panama, the Isthmus of Tehuantepec, and the U. S. West Coast. More vessels were added in 1850 and, in 1851, the service increased to semi-monthly trips up and down the coast.

The Panama railroad, constructed between 1850 and 1855, reduced the travel time from New York to San Francisco to 20 days. In the late 1860s, there were three Pacific Mail Line sailings from New York each month reaching Aspinwall on the eastern end of the Isthmus of Panama eight days later. Train time across the Isthmus plus sailing time up the coast to San Francisco was 12 days. Other passage times from New York were 42 days to Yokohama, and 50 days to Hong Kong.

Four beam-engined side-wheelers made up the transpacific fleet of the Pacific Mail Line in the late 1860s: the China built by William H. Webb, and the Japan, America, and Great Republic built by Henry Steers. They were almost identical ships: 380 feet on deck; 363 feet on waterline; beam, 50 feet; depth, 30 feet; and draft, 18 feet. They were iron strapped and double planked. The Pacific Mail Line grew from 3 ships, ordered in 1848, to 25 in 1867, with a total gross tonnage of 61,474. The line's growth was partially assisted by a Post Office Department subsidy of $500,000 per year that was authorized in 1864 for service from San Francisco via Honolulu and Japan to Hong Kong.

Three iron, propeller-driven steamers were constructed on the Delaware and went into service in 1873 on regular runs from San Francisco to Australia. These were the City of New York, the City of San Francisco, and the City of Sidney. A contract was also placed in that same year for the City of Peking and the City of Tokyo for service on the Japan-China run replacing the existing wooden side-wheelers. Each had a gross tonnage of 5,000 and was 408 feet long by 47 feet wide. Their 4,000-horsepower engines drove them at 13 to 14 knots making the trip from San Francisco to Yokohama in seventeen days--five days less than the wooden side-wheelers. The new ships cost $1.4 million each; the wooden side-wheelers they replaced had cost $1 million.

In 1874, the first tramp steamer made the round trip voyage from China to San Francisco and back. During that same year, some thirty steamers arrived in San Francisco from Hong Kong. Coastwise trade also added to the activity in San Francisco Bay. There were a number of small coasters, built on the West Coast, that were powered by steam supplemented by fore-and-aft sails. These were called steam schooners.

Coasters of this type had been used since the gold discoveries in the Frazer River in British Columbia in 1858. Pacific Mail steamers went into this service as well, carrying gold miners and their supplies from California and bringing back cargoes of furs and tallow for transport to the East Coast.

The Oceanic Steamship Company started a regular run from San Francisco to Honolulu, which was extended to Australia in 1883. The line was purchased by Matson in the 1920s. In 1901, the American Steamship Company put the steamer American into service between New York and Hawaii via Cape Horn and San Francisco. In that same year, the Dollar Steamship Company was formed; their ships engaged in tramp service.

Railroads contributed enormously to the expansion of the Pacific maritime trade. The effect of the completion of the Panama railroad in 1855 has already been noted. In 1869, the transcontinental railroad across the United States went into operation, providing an alternate route for passengers and cargo in transit to Hawaii and the Orient as well as to points up and down the West Coast. In 1907, a railroad was built across the Isthmus of Tehuantepec and ports were built on both coasts, the Port of Mexico on the Gulf side and Salina Cruz on the Pacific side. Salina Cruz was served primarily by American-Hawaiian 12-knot vessels with carrying capacities of 10,000 to 13,000 tons deadweight.

In 1913, the Spokane, Portland and Seattle Railroad Company placed orders for two express steamers--ships designed to make the passage from Astoria to San Francisco in the same time required for train connections between these points. They specified Parsons turbines directly connected to triple screws and 12 Babcock & Wilcox watertube boilers. Oil (which had been successfully tried on the Oceanic Steamship Company's Mariposa in 1902 and, more extensively, on the American-Hawaiian Line's Nebraskan in 1904) was adopted. Named Great Northern and Great Pacific, each of the 1913 ships was 524 feet in overall length; 500 feet between perpendiculars; beam, 63 feet; depth, 50 feet; and draft, fully loaded, 21 feet. Each carried 856 passengers, 198 crew, and a very limited amount of cargo with a total weight of only 2,185 tons. A feature of considerable investigation on these vessels was the subject of damaged stability. With the use of 10 transverse watertight bulkheads, a two-compartment ship was attained. Although intended for coastal service, they were in fact, small, fast, ocean liners, and, with a shaft horsepower of 23,000 and 10 of 12 boilers in operation, a speed of 23 knots could be maintained. During World War I, they proved to be very useful transports with fast passages and remarkably quick turnarounds.

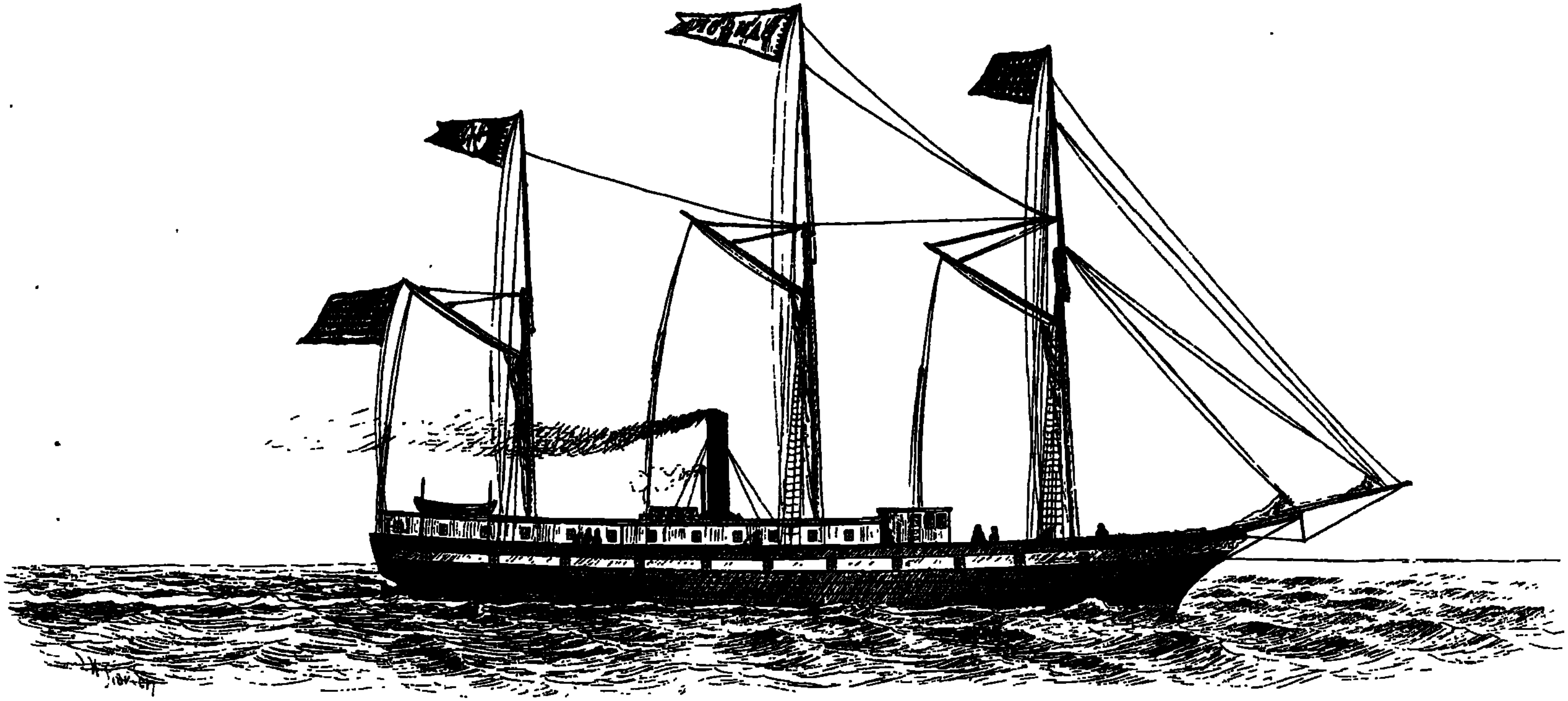
Bulk cargo carriers entered into the West Coast waterborne commerce at an early date. In the 1860s, shipments of wheat were sent from the Pacific coast to European markets, but the wheat was sacked rather than being carried in bulk. The principal bulk cargo was coal, much of it required to stoke the coal-fired steamers in the burgeoning Pacific coastwise and transpacific trades. Coal mined in British Columbia and Washington was carried south to the major ports in coastwise vessels. Coal was also imported from as far away as New South Wales, Australia, and Cardiff, Wales. Characteristically, since transit speed has never been a major factor in the bulk trades, sailing vessels were used as colliers for many years.

The first oil was discovered in California near the end of the nineteenth century. By 1902, a few of the transpacific steamers of the Oceanic Line had been fitted for burning oil. As more was discovered, and as methods were found to refine and burn this asphalt-base crude, the bulk trades expanded to include tankers to transport the oil to other parts of the world.

Another and unique form of bulk shipment originated on the West Coast to move lumber from Oregon to California. Rafts of logs were formed and lashed into a cigar-shaped configuration on the order of 600 feet long, 60 feet wide, and drawing 26 feet of water. These rafts, containing as much as 4 million board feet of finished lumber, were towed down the coast, with the tug or tugs deadheading on the return trip or towing oceangoing barges. This practice has continued with up to four rafts per year being towed--rafts of lengths up to 900 feet and total size equalling 7 million board feet.

In 1914, the opening of the Panama Canal changed considerably the magnitude and patterns of waterborne commerce on the Pacific coast. The water route from New York was reduced by 8,000 miles, directly affecting the many shipments that could not be transferred to the railroads for the Atlantic to Pacific crossing. The new route not only increased the trade between United States coasts, but also opened up the east and west coasts of South America to trade with the opposite coasts of the United States, Europe, and the Orient. The expanding waterborne commerce using the Panama Canal was slowed briefly during World War I, but thereafter increased at a rapid pace.

Shipbuilding on the West Coast began with wooden ship construction in the San Francisco Bay area and on the shores of Puget Sound. These yards mainly took care of local requirements and, at first, built only sailing vessels. Later, with machinery brought in from the East Coast, construction started on bay and river steamers and ferries.



BANGOR 1844

renamed USS SCOURGE 1846 redocumented SCOURGE 1848

Built at Wilmington, Del., iron, 212 tons, by Betts, Harlan & Hollingsworth Co. for Bangor Steam Navigation Co., route between Boston and Bangor, the first iron sea-going propeller steam vessel, and the second of that name. Burned and rebuilt in 1846 continuing same route. Sold in 1846 to U.S. government for use in Mexican War, renamed USS SCOURGE. Later sold to revolutionaries of Venezuela and seized by Venezuelan government as war prize in 1848.

Between 1850 and 1853, the Union Iron and Brass Foundry was established in a tent in San Francisco and began casting and machining ship components. After a series of owners and name changes, the company incorporated under the name Union Iron Works and moved to a new 32-acre site in the Potrero District facing San Francisco Bay. Its first steel vessel, the 200-foot collier Arago, was completed in 1884. She was followed by some 75 ships including several for the United States Navy and a cruiser for the Imperial Japanese Navy. Among the famous vessels built prior to 1900 were the battleship Oregon and Commodore Dewey's flagship made famous at Manila Bay, the cruiser Olympia, now on display to the public on the Philadelphia waterfront. In 1905, the yard was taken over by the Bethlehem Steel Company.

As American entry into World War I neared, West Coast shipbuilding activity accelerated. The British and Norwegians placed orders for freighters of 9,000 to 12,000 tons, deadweight, in Seattle, Portland, and San Francisco shipyards. Bethlehem acquired additional yards in the San Francisco Bay area, at Alameda and Hunters Point, and the Potrero yard expanded to operate the United States Destroyer Plant on the adjoining Pacific Rolling Mills property. These shipyards produced large numbers of cargo ships and destroyers, as well as components for British submarines, by the end of World War I.

Atlantic Commerce after the Civil War

The first large screw steamers built by American owners specifically for transatlantic service were the Erie and the Ontario. Built in 1885 at Newburyport, Massachusetts, these ships had wooden hulls and were 325 feet by 43 feet by 22 feet and were divided into five watertight compartments. Their slow-turning engines of 4,000 horsepower were geared up to turn the propeller at a higher speed. The gearing comprised a cast-steel pinion on the propeller shaft, which was driven by a large wooden-toothed gear mounted on the engine crankshaft.

The old side-wheelers were not easily dispossessed of their hold on oceanborne trade; the Pacific Mail Line built them as late as 1869. In 1872, the Old Dominion Line built a beam-engined coaster for their New York to Norfolk branch. She was, to all exterior appearances, similar to their ships of twenty years before that date. Named Old Dominion, she was built of iron, instead of wood, and saw 29 years of active service before grounding on Rye Beach in 1901.

The Harlan and Hollingsworth yard at Wilmington, Delaware, had built the iron, twin-screw vessel Bangor in 1843. Yet, between 1845 and 1870, only two of the yard's merchant steamers, out of 28, were screw propelled; the largest, at 1,600 tons, was the Salvador built for the Panama Railroad Company.

It was not until 1870 that American shipbuilders finally abandoned wood construction and turned exclusively to the iron-hulled single-screw steamer powered by a multiple-expansion engine and cylindrical firetube boilers. The shipyards engaged in building these ships, in addition to Harlan and Hollingsworth, Cramp, and Delaware Iron previously mentioned, were Pusey and Jones of Wilmington, Neafie and Levy of Philadelphia, and the Atlantic Iron Works in Boston. Between 1870 and 1880, Harland and Hollingsworth built 26 ships, 16 were screw propelled. Pusey and Jones had built both wood and iron craft prior to 1870, with the latter material in the minority. Neafie and Levy, in Philadelphia, had built iron ships, but only two exceeded 200 feet in length prior to 1870. These yards were the principal iron shipyards of the country; wood yards still lined the harbors and rivers of the East Coast.

An excellent example of the small iron screw-steamer of the post-war period was the William Lawrence built by Boston's Atlantic Iron Works in 1869. She was ordered by the Merchants and Miners Line, whose steamers had been running up and down the East Coast ever since 1852. The William Lawrence, 230 feet by 35 feet by 28 feet, had a small rig and a "chicken beak" bow.

After 1870, coastwise lines began replacing their rapidly decaying fleets with new ships. The Morgan Line, running to Gulf ports; the Merchants and Miners Line on the East Coast; the Oregon Railway and Navigation Company on the West Coast; the Mallory Line, connecting New York and Texas; Ward Line, running to the Bahamas, Cuba, and Mexico; the Savannah Line, and the Old Dominion Line were all flourishing in the coastwise trade. They all built up fleets of new vessels in the 1870 to 1890 period.

It is interesting that the cargo ship, as we know it today, did not appear in this country until the end of the nineteenth century. Throughout the latter half of that century, sailing ships of all sizes and rigs, still being built in large numbers, made up the greatest portion of our fleet. In fact, our first tramp freighter was the Winifred, ordered by A. H. Bull and Company from the Bath Iron Works in 1898.

A few ocean steamships in the U. S. Merchant Marine, and the numerous coastwise vessels, were reserved for passengers and fast freight; a very large majority had extensive accommodations and rather limited freight capacity. The Grecian, built in 1900, is an example. Her deadweight was 2,500 tons, 300 were taken up by coal and fresh water.

Quarters for 105 passengers were provided in the house and below the hurricane deck aft. Cargo was handled through side ports, two per side on the upper 'tween deck and two on the lower. Although she had 160,000 cubic feet of cargo space, it was broken up by three full decks below the hurricane deck and the hold itself was only 9 feet deep. The Grecian was built with a double bottom; a number of her contemporaries of up to 400 feet in length, on the other hand, were still single-bottom vessels. However, she still had the conventional row of centerline stanchions on every deckbeam which further interfered with stowage; stevedoring was cheap in 1900.

In those days, there were no damaged stability or floodable length requirements to influence the Grecian's naval architect; as a result, her forward hold extended from forepeak to machinery space, and her second hold from machinery space to afterpeak. The absence of cargo-handling gear is a characteristic of the time. A typical coaster was supplied with one cargo boom forward. Sometimes another was added aft; sometimes none were fitted.

On the engineering side of the ledger, steam pressures were rising rapidly, especially after the introduction of a triple-expansion engine in the steam whaler Balearic in 1883. By 1900, 250 pounds-per-square-inch boiler pressure had been reached in a number of merchant vessels.

Domestic steel was used in the construction of four naval vessels begun in 1883 at the Roach shipyard. As its quality improved, its use for hulls became more and more common.

In 1893, Cramp had under construction two Atlantic liners, Saint Louis and Saint Paul, for the International Navigation Company, an American firm that had taken over the Belgian Red Star Line and the English Inman Line. A protectionist Congress permitted two former Inman ships, City of New York and City of Paris, to be transferred to American registry provided American-built ships of the same size were constructed. The Saints aroused widespread interest at home and abroad; they represented the first American-built ships comparable in size and speed to foreign-built Atlantic liners since the last Collins liner, the Adriatic, was launched in 1856.

With a length of 535 feet 8 inches, a beam of 62 feet 9 inches and a depth of 42 feet 4 inches, they were about the average size of the Atlantic greyhounds of that era. Their displacement of 16,000 tons and speed of 20 knots equaled the White Star Line's Teutonic. The American ships had two six-cylinder, four-crank, quadruple-expansion engines, totaling 20,500 indicated horsepower.

In 1895, the Saint Louis and the Saint Paul were assigned to the Southampton route providing valuable additions to their owner's foreign-constructed fleet. As Spanish-American War auxiliary cruisers and World War I transports, they were equally successful. Both ships saw twenty-five years of almost continuous service before they were broken up in 1923.

The 1890s were of great importance in our country's shipbuilding history. True, our merchant fleet's tonnage in foreign service had dropped from the peak of 2.5 million tons in 1861 to a mere 800,000 in 1897, but our coastwise tonnage had risen from 2.8 million to almost 4 million tons. More important, however, was the qualitative fact that our designers and shipbuilders had caught up with the Europeans, and could produce commercial and naval vessels of the same caliber as those built abroad. Cargo steamers, starting with El Rio, El Sud, and El Sol, each about 400 feet long, built between 1890 and 1892 by the Newport News Shipbuilding and Dry Dock Company, marked the final decline of the sailing ship as the country's general cargo carrier. Oil tankers, starting with the Maverick, 1890, of 500,000 gallons capacity and the Atlas, 1898, 720,000 gallons, were built for the first time. In short, the decade, while not outstanding in the volume of ships built, was one of rapid progress in the art of shipbuilding and the sciences of naval architecture and marine engineering.

More large ships followed in the wake of the Saint Louis and the Saint Paul. From the Cramp yards came the Kroonland and Finland for Atlantic trade, a notable feature being the extensive use of pneumatic riveting in their construction. Newport News launched two 550-foot Pacific liners, Korea and Siberia, twin-screw ships, each of 18,400 tons displacement and 17,900 indicated horsepower. The Eastern Shipbuilding Company, in 1903, constructed the Minnesota and the Dakota, intermediate cargo and passenger ships, 608 feet in length, with a comfortable speed of 14 knots. In 1904, New York Shipbuilding Company added two more Pacific Mail liners, the Manchuria and the Mongolia--15-knot ships, 600 feet in length, displacing 26,500 tons, with two four-crank quadruple-expansion engines totaling 10,000 horsepower.

The year 1906 marked the introduction of two new elements in merchant ship engine rooms. The Creole, designed and built by Fore River Shipbuilding Corporation for Southern Pacific Lines, was a steel hurricane-decked freighter, 440 feet in length, with four cargo holds and passenger quarters accommodating 252. Aside from her two free-standing masts supporting five cargo booms each without shrouds or stays, she was a single-stacked coastwise ship. Nevertheless, her machinery was unlike that of any other ship of her class, for the Creole was powered with two ten-foot diameter reversing Curtis turbines, each 4,000 horsepower, directly connected to twin screws operating at 230 revolutions per minute. In addition, steam was generated at 350 pounds pressure and 100 degrees superheat by ten Babcock & Wilcox watertube boilers. The turbines, unfortunately, were less successful than the boilers and were later replaced by triple-expansion engines. The Governor Cobb, 1906, and the Harvard and the Yale, sister ships that made 21 knots on their trials in 1907, demonstrated the advantages of steam turbine propulsion in a more satisfactory manner.

Shipbuilding During World War I

As the nation geared up for its eventual entry into World War I, the Allies demanded more and more of America's maritime industry, lobbying for bottoms to transport the goods of war. It became a national policy to build an American merchant marine in order to replace tonnage lost to German submarine operations.

On May 7, 1915, the Lusitania was torpedoed. Shortly thereafter, other British steamers, the Arabic, the Ancona, and the Persia, to say nothing of numerous smaller vessels belonging to the allied nations, were sent to the bottom. Many neutral steamers, regardless of nationality or destination, were also sunk, until the total destroyed in 1915, according to British Admiralty reports, ran up to 1.8 million deadweight tons. The U-boats sank over 2.5 million deadweight tons, and it looked at that time as if Germany might continue to keep up, or possibly increase, that record. It was evident that the world's supply of ships was fast diminishing, and an urgent demand that the United States start building a merchant marine arose.

On September 7, 1916, Congress, recognizing that such a condition existed, passed an act "To establish a United States Shipping Board for the purpose of encouraging, developing, and creating a naval auxiliary and naval reserve and a merchant marine to meet the requirements of the commerce of the United States with its Territories and possessions and with foreign countries; to regulate carriers by water engaged in the foreign and interstate commerce of the United States; and for other purposes."

Under the Emergency Shipping Fund provision of the Urgent Deficiencies Appropriation Act, approved June 30, 1917, the President was, among other things, empowered "to place an order with any person for such ships or material as the necessities of the Government . . . may require during the period of the war and which are of the nature, kind, and quantity usually produced or capable of being produced by such person." The President was also authorized to exercise that power, and to expend the money appropriated, through such agencies as he might determine. This power was delegated to the United States Shipping Board Emergency Fleet Corporation by executive order. Thus, a national organization for building merchant ships was established, with an authorized budget of $500 million.

In the years just prior to the war, the total annual output of American yards only once exceeded 500,000 deadweight tons. It was believed that these yards could readily accelerate production to 2 million tons. But, at least 5 million tons were required to maintain a million-man army overseas to say nothing of transporting the men or of increasing the size of the expeditionary force. At least 3 million tons over and above what the established shipyards could produce in a year was needed; the question was how to obtain it. It seemed that the only way to make good the deficiency was to build a standardized, prefabricated ship that could be produced in quantity. With this method of construction, existing shops all over the country could produce the various components; a new shipyard would be established for the assembling of these parts or units.

The plan was to construct a mammoth ship assembling yard and to build numerous ships, all of the same design. In other words, to build a very large manufacturing plant and mass produce one type of standardized, prefabricated ship. This meant a simple ship design, one in which the plates, sections, angles, etc., could be punched and fashioned in structural steel and bridge shops, since these were the only steelworking plants available.

The scheme to build a shipyard five or six times as large as the largest in the country, and to assemble or manufacture ships as automobiles were manufactured, was a bold one. There were no precedents to follow, much pioneering work had to be done, and many engineering guesses had to be made. There was no time to make complete plans in advance, the work had to be started at once, and the development of the plans had to be made as the construction proceeded. The most desirable location, after eliminating all others was a tract of land on the Delaware River, near Philadelphia, called Hog Island.

The production of Hog Islanders, as the ships built there were called, was indeed impressive, and generated intense competition with yards located on the Great Lakes and along the West Coast. Existing shipyards expanded rapidly and new shipyards went into production. This expansion, as far as the West Coast was concerned, is illustrated by the increasing numbers of shipyards and building ways in the table below.

	1912-1913		April 1917		November 1918	
	Yards	Ways	Yards	Ways	Yards	Ways
Washington	2	7	11	32	24	120
Oregon	0	0	9	27	17	73
California	6	22	12	37	23	104
Totals	8	29	32	96	64	297

The Ninth, or Great Lakes, District of the Emergency Fleet Corporation was extremely proud of its production performance. The yards in this district produced 374 of the 1,141 ships built under the Emergency Fleet Corporation between 1917 and 1919. The Lakes ships were somewhat smaller than those built on the East and West coasts because of the size restrictions for transiting through the locks in the canal system between Lake Erie and Montreal; they were generally between 3,000 and 4,200 deadweight tons.

The total production of the entire country during these years, was as follows:

Fiscal Year	Ships	Gross Tons
1917	49	301,800
1918	410	2,570,000
1919	682	4,291,000
Totals	1,141	7,162,800

Ships were still coming off the ways when World War I ended, and, by 1921, the nation had 8 million gross tons of newly acquired merchant vessels. New construction slowed down. Many of the new yards closed; those that remained open reduced their personnel to a minimum.

The Period Between Wars

After the close of hostilities and the gradual return of requisitioned steamships to their original owners and routes, coastwise steamship services operated much as they had before the war. During the 1920s, new ships were ordered by almost all of the lines. The Savannah Line acquired the City of Chattanooga and the City of Birmingham, two new 380-foot ships, in 1923. In the same year, the Merchants and Miners Line followed suit with similar vessels, the Berkshire and the Allegheny. Eastern Steamship Lines ordered practically a whole new fleet. Their Acadia and St. John, both built at Newport News, were particularly handsome ships of over 6,000 gross tons and 11,400 shaft horsepower. East Coast, Gulf, and Caribbean ports saw a reasonable number of new, combination passenger-and-freight vessels between 1924 and 1932. Most of them were geared-turbine ships of moderate power, speed, and fuel economies, with steam pressures between 200 and 250 pounds, and with steam-driven auxiliaries.

The Dixie, built by Federal Shipbuilding and Dry Dock Company for Southern Pacific Lines in 1927, pioneered in higher steam pressures with 350 pounds per square inch and 100 degrees of superheat. Diesel engines, like geared turbines, had been introduced during World War I, but their initial cost, maintenance, and the heavy weight of the early engines largely offset their inherently better fuel economy;

their use in American oceangoing ships was not widespread. It was not until 1930 that the American-South African Line's City of New York appeared as America's first modern passenger-and-freight motor vessel. Built by the Sun Shipbuilding & Dry Dock Company, she was powered with two, four-cylinder Sun-Doxford opposed-piston engines of 2,700 horsepower each, driving twin screws. Her speed was 13½ knots. With a length of 450 feet, she carried 9,400 tons deadweight, and provided quarters for 56 passengers.

The first large post World War I ocean liner was the Malolo, built by Cramp in 1927 for the Matson Line's Pacific service. Shortly thereafter, President Hoover and President Coolidge, ordered by the Dollar Line from Newport News; three more Matson ships, Mariposa, Monterey, and Lurline II, from Bethlehem's Fore River Yard; and two Atlantic liners, Washington and Manhattan, from New York Ship, gave our merchant marine a series of modern vessels badly needed to replace older ships. They were intermediate-class passenger-and-freight liners with sustained sea speeds just over 20 knots. The Mariposa was 631 feet 6 inches overall; the President Hoover, 659 feet 3 inches; and the Manhattan, 705 feet. All were twin-screw vessels of generally similar appearance with conventional straight stems, extensive superstructure, and two stacks. The Mariposa had a full cruiser stern and the President Hoover a bulbous bow. The Dollar Line ships used turbo-electric propulsion, the others were driven by geared turbines. The Dollar Line's Manhattan, with a total of 30,000 shaft horsepower, was the most powerful as well as the largest; furthermore, she and her sister ship, the Washington, exceeded the requirements of the 1929 Convention on Safety of Life at Sea in both subdivision and fire protection.

It was not until 1939, however, that true fireproof construction was used in oceangoing passenger steamers. It was inaugurated in the Panama, the first of three similar vessels designed by George G. Sharp for the Panama Railroad Steamship Company and built by Bethlehem's Fire River Yard. The three ships, Panama, Ancon, and Cristobal, each 471 feet 6 inches by 64 feet by 46 feet 9 inches, carried 202 passengers in a single class, general cargo in five holds, and refrigerated cargo in two additional ones. Two double-reduction, cross-compound turbines, of 4,500 horsepower each, were supplied with steam at 445 pounds pressure and 750 degrees total temperature by a pair of A-type express boilers; continuous operating economy was insured by an automatic combustion control installation.

Riveting was used extensively in the Panama, although welding had, since 1930, been used to a significant extent, especially in tanker construction. Not until 1941, however, with the African Comet class of passenger-and-freight ships, built by the new Ingalls yard at

Pascagoula, Mississippi, from detail plans prepared by George Sharp, did our merchant marine have an all-welded, oceangoing passenger vessel.

Formation of the U. S. Maritime Commission

The Maritime Commission, organized as a result of the Merchant Marine Act of 1936, set up a ten-year building program in 1938. Merchant shipbuilding had reached a low ebb in the United States when the World War I boom collapsed, and had made only a slight revival under the Merchant Marine Act of 1928. Most of the fleet, having been built in 1918-1922, would soon be twenty years old, which was generally considered obsolescent. Out of 1,422 oceangoing vessels (2,000 gross tons and over) registered under the American flag, 91.8 percent would be twenty years old by 1942, as would all the 225 government-owned ships, most of them in mothballs from World War I. Most of the dry-cargo vessels were of 10- to 11-knot speed. Although 29 large combination passenger-cargo vessels had been built under the subsidy provisions of the Merchant Marine Act of 1928, the United States had no liners to rival the British *Queens*, and 60 percent of the combination passenger-freight vessels were near obsolescence.

The first ship contracted for through the Maritime Commission was the *America*, the largest liner ever built in the United States; the contract was awarded September 30, 1937. The *America* was not nearly as big as the huge luxury liners of the French and British, the *Normandie* and the *Queen Mary*, the record makers of the North Atlantic traffic. In some features, however, such as fireproofing, she exceeded even those famous ships, and constituted a notable advance in American passenger vessel construction. The *America*, to be operated by the United States Lines, was intended to give the American merchant marine a representation of which it could be proud in the most publicized of all trade routes.

Dry-cargo carriers, however, were needed more than the highly publicized liners, and fast tankers were wanted as auxiliaries for the Navy. Subsidies to increase the speed of *Cimarron* class tankers to 18 knots were among the first to be paid by the Commission; the extra speed was reckoned a defense feature. However, because American oil companies had kept up their tanker fleets, the glaring deficiency in the American merchant marine was the dry-cargo vessel. The Commission had to build fast, efficient freighters.

Merchant shipbuilding was booming as war drew nearer, and the revival of the industry was along the lines laid down by the Maritime Commission's long-range construction program--50 ships a year for ten years. In August 1940, the Commission voted to speed up that program so that 200 ships would be contracted for prior to July 1941. Before the end of October 1940, 47 ships had been delivered and contracts had been awarded for 130 more.

The ships designed before the war for the long-range program continued during the war to be the Commission's ideal of what they would like to build. They were commonly called "standard types" to distinguish them from the other main groups of ship types--emergency, military, and minor. Even under the pressure of war, the Commission succeeded in building so many of the standard types that its long-range program of completing 500 of these vessels in ten years had been exceeded by 1946. The standard dry-cargo carriers were designated C1, C2, and C3, the letter indicating that they were cargo ships and the number indicating their length between perpendiculars. Their main characteristics are shown below.

	C1	C2	C3
Length, overall	417' 9"	459' 6"	492" 0"
Beam, molded	60" 0"	63' 0"	69' 6"
Draft, loaded	27' 6"	25' 9"	28' 6"
Deadweight tonnage	9,075	9,274	12,500
Bale capacity, cu.ft.	452,420	536,838	732,140
Speed, knots	14.0	15.5	16.5

Compared to the freighters built before 1939, all of the C-types were remarkable for their speed. The Challenge, one of the first of the C2s, completed her maiden voyage from Boston to Cork, 2,742 nautical miles, in six days, 18 hours, and 38 minutes--an average speed of 16.82 knots, although the design speed of the C2 was only 15.5 knots. Because of better lines and improved propulsion machinery, these 15.5-knot ships had about the same fuel consumption per nautical mile as the earlier 11-knot ships. On sea trials in June 1939, the Challenge chalked up a new world's record for fuel economy with a fuel consumption of 0.552 pounds per shaft horsepower-hour for all purposes. Its high-speed cross-compound turbines developed 6,000 shaft horsepower and drove the propeller shaft at 92 revolutions per minute through double reduction gears.

Diesel engines, which did not require double reduction gearing, were installed on many C2s. Few diesels had been installed in American merchant vessels before the Maritime Commission launched its program, and its chairman, Vice Admiral Emory S. Land, USN (Ret.), considered recognition of the feasibility of the diesel engine to be one of the main contributions of the Maritime Commission to the technical development of the shipbuilding industry.

The other major contribution to which he pointed with pride in 1939 was the high-pressure, high-temperature steam turbine power plant being installed on C3s. Indeed, the C3 was an extremely fast ship for a cargo carrier. The design speed was 16.5 knots, but one of the first group built, the Sea Fox, on her official trials in March 1940 attained a speed of 19.5 knots and showed a fuel consumption rate of 0.563. These ships had a shaft horsepower of 8,500.

For tankers, design designations T1, T2, and T3 were used to indicate various sizes. Before 1941, however, the only tankers built with Maritime Commission aid were those of the high speed Cimarron class, the T3-S2-A1, which was built with designs furnished by the Standard Oil Company of New Jersey, and for which the Maritime Commission paid only the cost of defense features.

From the point of view of commercial operation, an essential feature of the C-types was their cargo-handling equipment. On most, this consisted of 14 or 15 five-ton booms and 1 thirty-ton boom. All were worked by electric winches. They were rigged to ten king posts which formed a prominent part of the profile characteristics of the C-types.

Welding was just coming into extensive general use on large merchant vessels. In the Commission's design, riveting was replaced by welding to such an extent as to save a substantial amount in the weight of the hull and so obtain greater deadweight carrying capacity. The proportions of riveting and welding varied from yard to yard. The Exchequer, a C3 built by the Ingalls Shipbuilding Corporation at Pascagoula, was the first all-welded ship to be completed under the Maritime Commission shipbuilding program; it was 600 tons lighter than other C3s.

In the lean years from 1922 to 1938, only the very strong shipbuilding companies were able to keep going. The strongest survivors were Newport News, Federal, New York, Sun, and Bethlehem. Because of their equipment, the high reputation of their engineers, the location of their yards, and their corporate or banking affiliations, they were the best placed for securing the scanty orders for tankers, ore carriers, and Navy ships which offered some nourishment during the barren period.

The Newport News Shipbuilding and Dry Dock Company was the oldest and perhaps the most experienced in the country. It had been founded in 1890 and since that time had built ships of all kinds, including battleships. In 1940, it was outfitting the America. The Federal Shipbuilding and Dry Dock Company of Kearney, New Jersey, was a subsidiary of U.S. Steel. The New York Shipbuilding Company at Camden, New Jersey, founded in 1899, had built battleships, cruisers, and passenger liners. The Sun Shipbuilding and Dry Dock Company, Chester, Pennsylvania, was a subsidiary of Sun Oil Company and constructed many tankers for that concern and other oil companies. Bethlehem Steel's biggest yard was the Fore River yard at Quincy, Massachusetts. Its Sparrows Point yard at Baltimore was also important, and there was a smaller yard at Staten Island, New York. Bethlehem's repair facilities included not only docks at East Boston, Brooklyn, Baltimore, and Hoboken, but also facilities on the West Coast in San Francisco Bay and at San Pedro. Bethlehem reopened the old Union Iron Works yard on San Francisco Bay so as to join the Maritime Commission's long-range program.

When war began in Europe and shipping boomed, new companies entered the field. The new yards, and the work underway in 1940, were:

1. Tampa Shipbuilding and Engineering Company, at Tampa, Florida, building diesel-powered C2s on three ways;

2. The Ingalls Shipbuilding Corporation, at Pascagoula, Mississippi, building C3s on four ways;

3. Pennsylvania Shipyards, Incorporated, at Beaumont, Texas, had laid the keel for a C1;

4. Consolidated Steel Corporation, Limited, at Long Beach, California, building two C1s in the one long way in their recently acquired Craig yard;

5. Western Pipe and Steel Company, at San Francisco, building two C1s;

6. Moore Dry Dock Company, at Oakland, California, primarily a repair company with three ways, outfitting three C3s;

7. Seattle-Tacoma, Washington, two C1s on the ways, three in outfitting;

8. The Pusey and Jones Corporation, at Wilmington, Delaware, building a C1;

9. Gulf Shipbuilding Corporation, at Chickasaw, Alabama, building two C2s;

10. Alabama Dry Dock and Shipbuilding Company, at Mobile, a private tanker;

11. Welding Shipyards, Incorporated, at Norfolk, Virginia, a private tanker.

The yards working on large merchant ships at the end of 1940 totaled 19.

Chapter 5

MERCHANT SHIPBUILDING DURING WORLD WAR II

Before Pearl Harbor, the United States was gradually being drawn into World War II. Despite the accelerated construction under the auspices of the Maritime Commission, the American merchant marine's ability to carry wartime cargoes was relatively no better off than it had been at the start of the Revolution, the War of 1812, the Civil War, the Spanish-American War, and World War I. What we did have for this war, however, was a governmental organization staffed by highly qualified members of the maritime community and headed by a far-sighted, tough, and capable leader, Admiral Emory S. Land, who had the full confidence of the Congress and of the President. Furthermore, a national shipbuilding program was in place, new designs were completed and in production, and both old and new shipyards were expanding their capacities at a rapid rate. Thus, although we did not yet have many ships, we had a strong foundation upon which to mount a massive construction program to meet the most stringent demands ever imposed upon a single nation--the maritime needs of the free world.

The Liberty Ship Program

Under these conditions, three emergency shipbuilding programs were added to the accelerated long-range program during 1941. They comprised three waves of expansion. The first consisted of 60 ships contracted for by the British and 200 for the United States. The second wave came in April after Congress passed an act providing for transferring merchant ships and other forms of aid to Britain under lend-lease. The third rolled in gradually during the rest of the year, until, on December 7, 1941, the Japanese attack opened the floodgates for two even bigger waves of shipbuilding expansion.

The British were prepared to back an extensive program involving the construction of new yards in late 1940, which they recognized could not be expected to produce any ships before 1942, and they discovered at once that they could not have fast ships. There were not enough of the needed turbines and gears, not even enough to supply the Navy and the Maritime Commission's long-range program. They then obtained permission to build 11-knot, 10,000-ton freighters.

Workmen were just clearing the sites where the British ships were to be built when President Franklin D. Roosevelt announced, on January 3, 1941, that the United States would build 200 similar ships. The British had been urging action of this kind. "Looking into the future," wrote Prime Minister Winston S. Churchill, "it would seem that production on a scale comparable to that of the Hog Island scheme of the last war ought to be faced for 1942."

Admiral Land did not relish the idea that the United States build 11-knot freighters such as the British would have to build. He wrote, "The last thing I want to do is to repeat the mistakes of the last war and have a lot of obsolete vessels on our hands unless the emergency is so great as to make this an absolute necessity." A month later the emergency had grown, and the building of 200 simple cargo ships for American registry, in addition to the 60 for the British, had become an accepted objective of the Maritime Commission. "The proper procedure for the production of ships in quantities," Land wrote on November 8, "is to settle on the type of ship, which in quantity production for quick delivery (considering the excessive load on the auxiliary building and turbine building capacity of this country) is a simple type of cargo ship with reciprocating engines, boiler pressure of 200 to 220 pounds, with all steam auxiliaries." These emergency ships became known as Liberty ships with the designation EC2.

Once a quantity production program was decided upon, the selection of shipyard sites became a pressing issue. At the opening of 1941, nine yards, with a total of 65 ways, were approved, and work on the 260 ships, to be built in two years, began at the following locations:

	Ways
South Portland, Me. -- Todd-Bath Ironworks Shipbuilding Corporation for the British	7
Baltimore, Md. -- Bethlehem-Fairfield Yard	13
Wilmington, N.C. -- North Carolina Shipbuilding Company	6
Mobile, Ala. -- Alabama Dry Dock and Shipbuilding Company	4
New Orleans, La. -- Delta Shipbuilding Company	6
Houston, Tex. -- Houston Shipbuilding Corporation	6
Los Angeles (Terminal Island), Cal. -- California Shipbuilding Corporation	8
Richmond, Cal. -- Todd-California Shipbuilding Corporation for the British	7
Portland, Ore. -- Oregon Shipbuilding Corporation	8

The second wave of expansion was directly linked to congressional approval of the lend-lease program. That approval was tied to a provision for more Liberty ships, for more C-type freighters, and for government-built tankers.

After lend-lease was provided for by the Defense Aid Supplemental Appropriation Act, Admiral Land was called to advise on the allocation of funds for about 200 more ships. He successfully urged that at least half that number be C-types. Tanker construction was also decided on.

The Office of Production Management, however, approved 306 new ships, and they were incorporated in the Maritime Commission's program of April 1941: 112 EC2s, 24 C1s, 46 C2s, 52 C3s, and 72 T2-SE-A1 turbo-electric driven tankers. With speeds of 14 to 15 knots and a dead-weight tonnage of 16,655, these tankers were considerably bigger and faster than the emergency ships. They became a very substantial element in the output of the Commission's yards.

More shipways were needed to build the added standard and emergency cargo ships. They were provided by adding to yards of existing companies.

At the same time, the emergency yards, which were just starting, were told to increase the number of ways: Bethlehem-Fairfield from 13 to 16, California Shipbuilding from 8 to 14, Oregon Shipbuilding from 8 to 11, Todd-Houston from 6 to 9 and North Carolina from 6 to 9. The two managements building yards for the British were given contracts to construct new yards next to those already being built; at South Portland, Maine, a new four-way yard under a new corporation, the South Portland Shipbuilding Corporation; and at Richmond, California, a new six-way yard, commonly known as Richmond No. 2, under the Richmond Shipbuilding Corporation, a subsidiary of Kaiser's Permanente Metals Corporation.

The new facilities for the third wave involved no new yards, except those for building minor types. In emergency yards, two ways were added at the Delta yard in New Orleans, two at the yard of South Portland Shipbuilding, and three at Richmond No. 2.

The Liberty ships basically had the same hull form and characteristics as the cargo ships built for the British except that they were oil fired, instead of coal fired, and used watertube boilers, instead of Scotch (firetube) boilers. The plans, adopted from those which the Gibbs & Cox naval architectural firm had prepared for the British, called for a ship with the following dimensions:

Length, overall	441' 6"
Beam, molded	56' 11"
Draft, load	27' 8"
Deadweight tonnage	10,419
Bale Capacity, cu. ft.	500,245
Speed, knots	11.0

They were powered by 2,500 IHP steam reciprocating engines. Turbines and gears were in short supply due to Navy and Maritime Commission standard ship production.

Liberty ships bore the Maritime Commission designation EC2-S-C1 (Emergency Cargo, length 400-450 feet, steam, Design C1). By the end of World War II about 2,500 had been built in the shipyards listed below; the total number eventually reached 2,708.

	Ships
Delta Shipbuilding, New Orleans, La.	128
Jones-Brunswick, Brunswick, Ga.	85
Jones-Panama, Panama City, Fla.	66
St. Johns River Shipbuilding, Fla.	82
Southeastern Shipbuilding, Savannah, Ga.	88
Todd-Houston Shipyard, Houston, Tex.	208
California Shipbuilding, Terminal Island, Cal.	306
Permanente No. 1, Richmond, Cal.	138
Permanente No. 2, Richmond, Cal.	351
Oregon Shipbuilding, Portland, Ore.	330
North Carolina Shipbuilding, Wilmington, N.C.	126
Bethlehem-Fairfield, Baltimore, Md.	361
New England Shipbuilding, South Portland, Me.	228
Total	2,498

Tugs, Barges, and Miscellaneous Vessels

The third wave of the World War II build-up included, in addition to the standard types of ships and expansion of the emergency ship construction program, a number of coastal cargo vessels for the British, seagoing tugs, concrete barges, and ore carriers.

The coastal cargo vessels, designated N3-S-A1, were each 254 feet by 42 feet by 20 feet with 1,300 IHP reciprocating steam engines. Many of these were built in Great Lakes shipyards since their size permitted them to make their way to the Atlantic via the Great Lakes and St. Lawrence route. Other small yards, such as Ingalls barge building yard in Decatur, Alabama, were utilized. One group of these ships, built in the Leatham D. Smith yard in Sturgeon Bay, Wisconsin, were powered by Ajax steeple-compounded uniflow engines; this was but one example of the need to use every available manufacturing facility to produce ships' machinery under wartime conditions.

A very powerful class of seagoing tugs, the V4-M-A1, was built in Great Lakes yards and other yards on the East and West coasts. These ships were each 194 feet by 37 feet 6 inches and displaced 1,600 tons at a keel draft of 15 feet 6 inches; the draft over the Kort nozzle surrounding the propeller was 17 feet. They were powered by two 6-cylinder, supercharged diesel engines driving a single propeller through a reduction gear for a total of 2,250 BHP. These 14-knot tugs had a dead-pull capacity of over 100,000 pounds. Because of the excessive draft of the nozzle, the ships built in the Great Lakes could just barely be trimmed enough down by the bow to make it over the lock sills in the St. Lawrence exit route.

The building of concrete ships had been tried during World War I with results that moved Admiral Land to declare to a House committee in January 1941: "Personally, you are not going to get any from me as long as I am Chairman of the Maritime Commission. If you gentlemen start building concrete ships, as far as I am concerned, I am through." He abandoned that attitude under the pressure of war. While remaining doubtful of the wisdom of building concrete vessels, he considered it a minor matter, certainly not a sufficient reason for resigning his post in time of war. He and the Commission yielded to the various pressures that gradually edged them into it.

The opening wedge was inserted during the first scare over the shortage of steel plate, in June 1941. Something had to be done to increase the movement of petroleum products from Texas to the Northeast. The shipbuilding fraternity, not in favor of land transport, felt the existing barge program provided an argument against building a pipeline. But, a shortage of steel existed, and the Technical Division of the Maritime Commission recommended that tow barges be built of reinforced concrete. It envisaged building 50 or 60 during the first six months of 1942. It recognized that concrete construction would "require at least half the steel of an all steel hull," but the steel would be in the form of bars of low carbon content and would thus avoid the wartime shortage of plate or strip. The director of the Technical Division, James L. Bates, supported the use of concrete primarily because he hoped to avoid another horrifying attempt, like that of World War I, to build those "beautiful wooden ships" for which President Roosevelt and other yachtsmen were openly enthusiastic.

Against this background, negotiations were opened with interested contractors, and conferences were held with the engineers who had worked on the many technical problems involved and were enthusiastic about the possibilities of their specialty. Bates reported that the Technical Division was not only receiving "hearty cooperation from a number of strong companies," but also "a somewhat embarrassing interest from regional and political sources." In November, contracts were awarded to three companies to build five barges each.

The three selected proposals, from a field of 64 bidders, suggested two different designs. One design was designated the B7-A1 and was used to build barges in Savannah, Georgia, and Houston, Texas. The other design, B7-A2, was used in National City, California. The former was 366 feet by 54 feet by 35 feet, displacing 10,940 tons with a 5,400-ton cargo capacity; the latter was 375 feet by 56 feet by 38 feet displacing 12,890 tons with a 6,300-ton cargo capacity.

In addition to 33 of these oil barges, other types of concrete barges were built during the war including: 20 dry cargo barges, 22 dry stores lighters, 3 reefer stores lighters, and 2 repair-shop lighters. Twenty-four self-propelled concrete dry cargo steamers were also constructed. The total deadweight capacity of concrete construction vessels built during World War II was 488,100 tons.

To maintain the flow of iron ore from Lake Superior to the foundries, the construction of 16 ore carriers was declared essential. Both the Great Lakes Engineering Works in Detroit and the American Shipbuilding Company in Cleveland submitted bids based upon similar designs designated the L6-S-B1 and the L6-S-A1 respectively. The ships were each 620 feet by 60 feet by 34 feet. At a draft of 24 feet, they displaced 21,000 tons with a deadweight capacity of 15,840 tons. The L6-S-A1s were driven by four-cylinder, double-compound poppet-valve Lentz reciprocating engines of 2,500 IHP; the two watertube boilers were coal-fired, using automatic stokers with coal crushers and self-dumping grates. Their speed was 12.5 miles per hour. The L6-S-B1s used Great Lakes Engineering Works triple-expansion reciprocating steam engines. In other respects the ships were nearly identical. American Ship produced six of these ships in their Lorain yard and Great Lakes delivered ten.

Between 1943 and 1945, at the request of the Navy, a class of small cargo vessels was constructed. These were each 338 feet by 50 feet by 29 feet and displaced 8,300 tons at a mean draft of 23 feet 5 inches. The design designation was C1-M-AV1 and some 208 of these vessels were built. They were powered by a single 1,700-horsepower diesel engine turning at 180 RPM and directly connected to the propeller without gearing.

A large number of these ships were built in Great Lakes shipyards at Milwaukee, Sturgeon Bay, and Superior, Wisconsin. All quarters and control spaces were in an after deckhouse and, in light ship condition, they trimmed considerably by the stern. In order to get these Lakes-built ships to sea via the Illinois-Mississippi Waterway, it was necessary to cut off two levels of the deckhouse and stow this structure on the main deck forward. Additionally, some six pontoons were secured below the counter at the stern. Only in this way was it possible to clear beneath the fixed bridges and clear the bottom of the waterway between Chicago and St. Louis.

Ten ships of almost duplicate design were built as fully refrigerated cargo ships (R1-M-AV3). Both refrigerated and non-refrigerated types were used mainly in the Pacific theater during World War II.

The Victory Ship Program

In 1943, while the yards were setting their all-time record in the production of Liberty ships, the schedulers and designers in the Maritime Commission were making preparations for the production of various new types, of which the most important was the Victory ship, a faster type of cargo carrier. Construction would be in the emergency yards.

One reason for this change was the continuing steel shortage. The fastest yards were going to be forced to slow down in order not to run out of steel. Consequently, the Commission planned to put its allotted steel to more efficient use by building faster ships. When lack of steel limited the program for 1943 to 16 million tons, the Commission called for building as much as possible of that tonnage during the first half of the year, for the carrying capacity was needed as soon as possible. During the later months of the year, when production would have to slow down, yards could afford the time to change over to a new type.

Another reason for a change, a reason that might have caused diversification in the program even if there had been no steel shortage, was the cumulative effect of demands for faster ships. The Navy needed C2 and C3 cargo ships for conversion to tenders and other auxiliaries; and faster cargo carriers were required for wartime use and for postwar competition.

While the main problem, propulsion machinery, was still unsolved, the Commission's Technical Division worked out a basic design for the new vessel, with slight modifications to allow reciprocating engines, diesels, or turbines to be used. From the start, it was clear that the box-like design of the Liberty would not serve for a ship designed to make 15 knots. Assuming a reciprocating engine of 5,600 horsepower and about 100 revolutions per minute, the basic dimensions of a design called the AP1 were worked out, in September 1942, as follows:

Load Waterline Length	445' 0"
Beam	63' 0"
Depth	38' 0"
Designed draft	28' 0"
Designed speed (80 percent of designated power)	15 knots
Designed power	5800 IHP
Number of holds	5

While the form of the hull was being worked out, the characteristics of the propulsion machinery were still in doubt. The hull lines had been planned on the assumption that the ship would have an engine of 6,000 SHP and a speed of 15 knots. It became apparent, however, that turbines of 5,800 SHP might be available for some ships of the new type. As finally developed, the Victory cargo (VC2) ship used slightly more power at a 15-knot speed than did the C2; but, in spite of its greater deadweight tonnage, it used less power than the C2 at speeds of 16 knots or more.

By the end of March 1943, the characteristics and specifications for the new ship were settled. Since the new vessel grew out of the Liberty ship, the basic idea being a vessel of the same deadweight, but with 15-knot speed, it is interesting to compare it with the Liberty. They were both full scantling ships with five holds, the machinery space being between holds No. 3 and No. 4. Cargo-handling gear was also similar, consisting, on the new ships, of fourteen 5-ton booms, one 30-ton, and one 50-ton. Unlike the Liberty Ships, it had an extra deck in holds No. 1, No. 2, and No. 3 for the stowage of package goods, and used electricity rather than steam for anchor windlass, for steering, and for some pumps.

Initially, it was planned to use Lentz engines in most ships of the new type (the VC2-S-AP1). The designers also completed plans for use of other engines. The designation VC2-S-AP2 was given to a design providing for the 6,000 SHP C2 turbine; the VC2-S-AP3 was the same vessel when provided with an 8,500 SHP C3 turbine; the VC2-S-AP4 was a design using diesel propulsion. After many delays and problems within the many governmental organizations involved, the VC2-S-AP3 with an 8,500 SHP turbine became the standard.

The first Victory ship to be built was delivered by Oregon Shipbuilding on the last day of February 1944. Only 15 were delivered before May 1944: 11 from Oregon Shipbuilding and 4 from California Shipbuilding. Later Victory ships were also built at Bethlehem-Fairfield, Richmond No. 1 and No. 2, and Vancouver. All the Victorys built at the latter yard were the modified form of the Victory design, which began in May 1944 to fill the shipways of the West Coast Victory yards, namely, the VC2-S-AP5, the attack transports. Altogether, the Maritime Commission built 414 Victory cargo ships and 117 Victory transports. As matters worked out, the best justification for introducing the Victory design was its adaptability to the need for transports.

Chapter 6

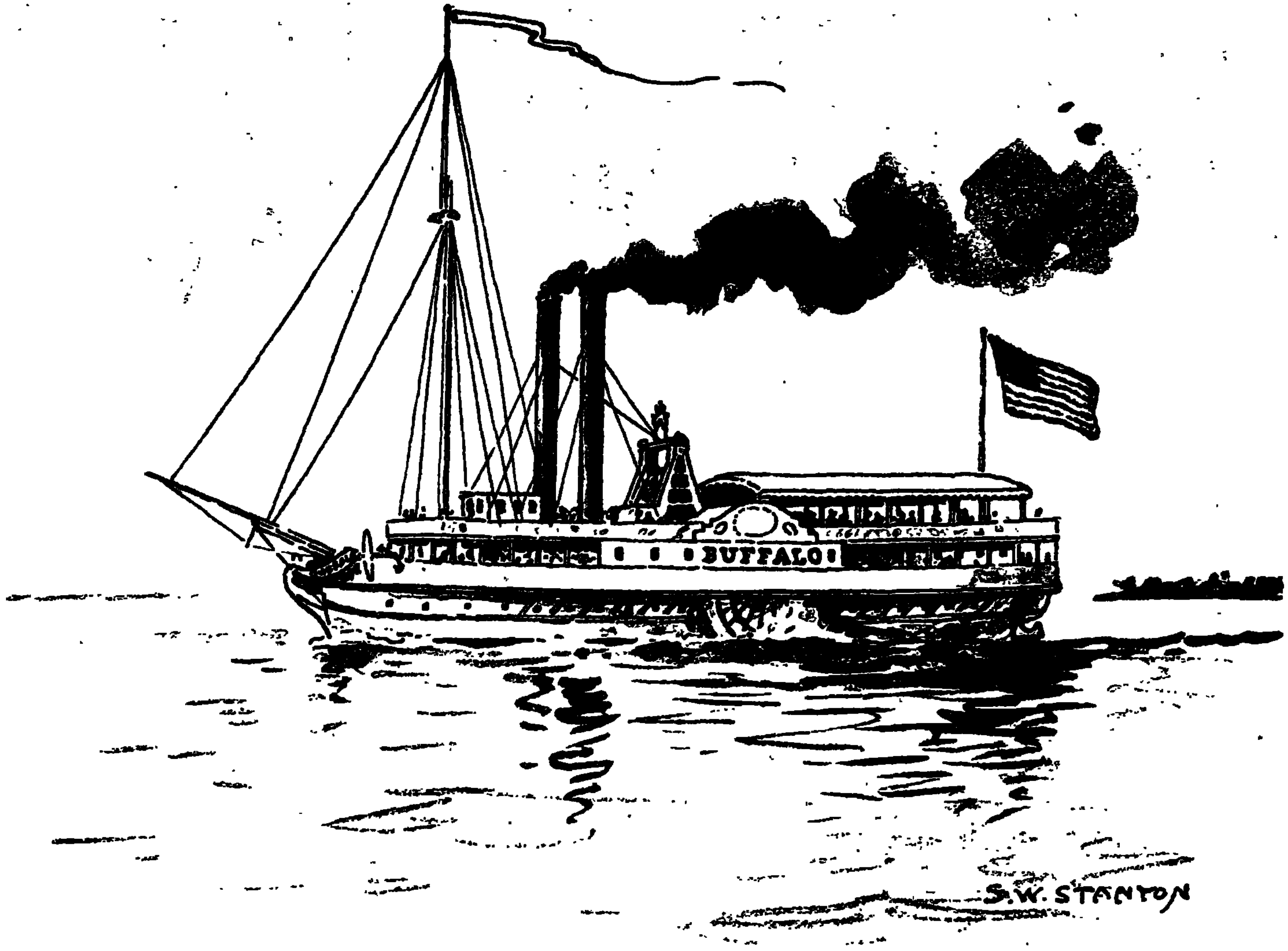
DEVELOPMENT OF SHIPPING ON THE GREAT LAKES

The Great Lakes Basin includes the five major lakes: Ontario, Erie, Huron, Michigan, and Superior, which have surface areas ranging from about 7,500 to 32,000 square miles. It includes many other lakes, from St. Clair, with a surface area of 490 square miles, down to many smaller bodies of water. The watershed area is about 295,000 square miles, of which some 95,000 square miles represent the area of the five Great Lakes. The drainage, from the heads of the system in the Superior and Michigan basins, proceeds through Lakes Huron, St. Clair, Erie, and Ontario to the St. Lawrence River and thence to the Atlantic Ocean. The entire system constitutes a waterway extending nearly halfway across the North American continent.

Lake Superior, with a surface elevation of 602 feet above sea level and a maximum depth of 1,333 feet, has a relatively smooth northeast-southwest trending basin in its western half, where depths in excess of 600 feet are fairly common. Its eastern third is strongly ridged, with depths over the ridges commonly in excess of 500 feet and depths in the hollows from 800 to 1,000 feet.

Lake Michigan has a surface elevation of 580 feet and a maximum depth of 923 feet. Its southernmost third is a relatively smooth basin where a depth of 564 feet occurs. Relatively shallow water, 300 feet deep, covers the mid-lake area, while a main northern basin contains the greatest depths of the lake. In the northeastern end of the lake, a straits area, a distinct channel is incised in a relatively smooth shallow shelf.

Lake Huron, with a surface elevation of 580 feet and a maximum depth of 750 feet, is separated from Georgian Bay and the North Channel, to the northeast and north, by a nearly continuous barrier formed by Saugeen Peninsula and Manitoulin and several other islands. Lake Erie, surface elevation 573 feet, has a maximum depth of 210 feet and an average depth of about 60 feet. This relatively shallow lake contains about one-thirtieth the volume of Lake Superior, and is the only one of the Great Lakes whose bottom does not extend below sea level. Lake Ontario has a surface elevation of 246 feet and a maximum depth of 804 feet. It is a relatively smooth trough but it is asymmetrical, with the axis of its deepest portion lying south of the mid-line.



BUFFALO 1838

Designed by Captain Church, built at Buffalo, New York, wood, 613 tons, by John Carrick, for C. M. Reed and others, Buffalo and Detroit route. Launched as MANHATTAN to please a New York stockholder, but registered and ran as BUFFALO. Converted into bark 1848, and sank in same year in Lake Michigan.

Initial Waterborne Commerce on the Lakes

Early navigation on the Great Lakes was by birchbark canoe which served its purpose well, being light and easily handled by a crew of six or eight. Typical canoes for transporting hides and pelts averaged 32 to 35 feet in length and 5 to 6 feet in width. It is said that a large canoe would carry three tons of valuable furs and also six to eight men with all their camp equipment.

Robert Cavelier, Sieur de La Salle, received a charter in 1677 to build vessels on the Mississippi River and on the Great Lakes and to trade in these areas. La Salle built the first sailing vessels on Lake Ontario in 1678, and used them to ferry men and supplies across the Lake to build a shipyard on the east bank of the Niagara River. There he built a barque, the Griffon or Griffin, which set sail in August 1679 across Lake Erie, through the Detroit River and into Lake Huron. Reaching Green Bay on the western shore of Lake Michigan, La Salle had the ship loaded with furs collected there for him, and ordered the ship back to Niagara while he remained behind to explore Lake Michigan. The ship departed in September 1679 and was not heard from again.

In 1701, the French established a fort on the Detroit River, which connects Lake St. Clair to Lake Erie, to maintain control of the Great Lakes fur trade against incursions by British colonists pressing westward from their coastal colonies. Their control was lost in 1760 when they surrendered to the British at Quebec ending the French and Indian Wars. The defeated French were no longer able to preserve the wilderness areas along the lakes for the fur trade alone, and settlements were established along the southern shores of Lake Ontario and Lake Erie. Inevitably, trade developed between these settlements and sailing vessels of increasingly larger capacity were used to move agricultural products and supplies back and forth across the eastern lakes.

In the War of 1812, the United States challenged British control of the Great Lakes region. The British built six vessels in the Fort Detroit area; the Americans built nine near what is now Erie, Pennsylvania. In September 1813, the latter, under the command of Oliver Hazard Perry, met the British fleet off Put-in-Bay and, after a three hour battle, were victorious. With the Treaty of Ghent in 1814, the Americans attained complete control of the Great Lakes.

Steamboat construction began on the Great Lakes in 1816 with the Frontenac, built on the Canadian side in Kingston, Ontario. The next steamer, Ontario of 232 tons, built at Sackett's Harbor, New York, was launched that same year. In 1818, the Lake Erie Steamboat Company was formed and built the Walk-in-the-Water at Black Rock, New York. This vessel, with an overall length of 135 feet and a gross tonnage of 338, was rigged as a two-masted steam schooner. At a maximum speed of about seven miles per hour, she made the trip from Buffalo to Detroit in four days with stops at Dunkirk, New York, and at Erie, Cleveland, Sandusky, and Venice, Ohio.

In 1834, the John Jacob Astor was built on Lake Superior and this was the first vessel to fly the American flag on that body of water. Chicago and Detroit were then only trading posts, and practically all bulk freight on the Lakes was carried in sailing vessels, of which the largest was of some 1,800 tons capacity. Towed by tugs, singly or in fleets, through the rivers between Lakes Superior and Huron or Lakes Huron and Erie, they made the rest of the trip under sail alone.

The Ontario and Walk-in-the-Water were followed by other steamers and by the late 1820s about twenty steamers worked on the Lakes. When the Welland Canal was opened, soon after 1829, the width and length of its locks fixed limits to the dimensions of steamers and sailing vessels alike for many years. The construction of larger steamers began about 1845, when fast side-wheelers were built for the passenger trade. Propellers as well as side paddle wheels were used, the first being on the Vandalia, built in 1841 as Oswego, New York.

The growing trade in iron ore, grain, lumber, and coal later produced a special type of lake steamer whose dimensions were controlled by the changes made in the Welland Canal and by other restrictions. This vessel had its machinery well aft; it was a flat-floored, wall-sided, rather straight-sheered vessel with short, full ends; the hull was long and narrow and was heavily trussed to give longitudinal strength. The design was largely established by the steam barge of the 1870s which had a long and narrow, full-ended hull of moderate sheer with short counter, usually round or elliptical, a vertical straight stem, and was schooner rigged with two to four masts, but without a bowsprit. Where there was a two-deck superstructure, the engine and boiler were aft. Many of the barges carried topmasts and some of the four-masters had no sail on the aftermast, it was employed as a derrick mast only.

As the small outposts along the lakeshores grew into full-fledged centers of commerce, lake trade showed a concomitant expansion. During the two decades between 1836 and 1856, the numbers, kinds, and sizes of ships increased as shown in the table below, extracted from various sources.

Year	1836	1846	1856
Number of sailing vessels	217	407	1,149
Tonnage of sailing vessels	16,645	46,011	143,625
Number of paddle-wheel steamers	45	67	120
Tonnage of paddle-wheel steamers	9,119	43,820	78,500
Number of propeller steamers	0	26	118
Tonnage of propeller steamers	0	17,000	77,200

Iron Deposits Generate a New Transportation Link

In addition to the known deposits of copper along the southern shore of Lake Superior, iron ore deposits were discovered near Marquette, Michigan, as early as 1844. However, the commercial development of the mines had to await the opening of the Michigan State Lock in the St. Mary's River in 1855. The first ore carrier through the locks was the 91-foot brigantine Columbia with a cargo of 132 tons of iron ore from Marquette, bound for Cleveland. Shipments of ore that year amounted to 1,449 tons; total traffic, all commodities, through the new locks between Lakes Superior and Huron reached 14,503 tons during the navigation season.

The iron ore mines were situated at the upper, or northwest, end of the Lakes, while the coal mines were adjacent to the lower, or southeast, end. Ore and coal had to be brought to a common point to produce iron. Economics dictated bringing the ore to the coal, and the district between Lake Erie ports became the center of the iron and steel industry. The rail haul is short from such ports as Cleveland, Erie, Conneaut, and Astabula to the center of Pittsburgh.

Another important commodity required for the production of iron is limestone. There are a number of limestone quarries on the Lakes; probably the most notable is located at Rogers City, Michigan, convenient for transportation to either Lake Erie or Lake Michigan ports. The movement of iron ore, coal, and limestone for the steel industry formed the foundation for bulk shipping activity on the Great Lakes. The other major bulk commodity was grain, carried from Duluth and Superior to southern and eastern Great Lakes ports.

In 1869, the first steam barge, the R. J. Hackett, the prototype of the modern lake freighter, was built. She marked the transition from sail to steam for bulk-cargo shipping on the Great Lakes, and was the beginning of the present fleet of Great Lakes bulk-cargo carriers. She was 211 feet long, with a beam of 32 feet and a depth of 20 feet 5 inches, and carried about 1,000 tons.

About 1880, wooden shipbuilding became very expensive on the Lakes and there was a gradual shift to iron and then to steel construction. Late in that decade the use of sails on lake steamers went out of fashion. Within a few years, the forerunner of the modern ore and bulk-cargo carrier of the Lakes appeared, with pilothouse right forward and the engine, boiler, fuel, and a deckhouse for crew's quarters at the extreme stern.

The steamer Onoko, built in 1882, remained the largest vessel on the Great Lakes in 1885, her dimensions being 302 feet 6 inches in overall length; 38 feet 6 inches, beam; and 24 feet 8 inches, depth. This steamer was the first on the Great Lakes to be built of iron: when her launching was announced, a great crowd gathered, expecting her to sink at once. Her gross tonnage was 2,164 and her deadweight was nominally rated at 3,000 tons, although she is said to have carried as much as 3,800 tons of iron ore. The Onoko was the marvel of her time. In 1885, she arrived at Buffalo with 87,400 bushels of wheat--9,000 more than had ever been taken out of Duluth in a single bottom. In the same year, she carried the largest cargo of iron ore that had ever been transported, 3,073 tons. Later, with 92,013 bushels of wheat, she again broke all records.

In 1886, the Glove Iron Works of Cleveland, the same yard that had built the Onoko, turned out its first steel-hulled ship. The Spokane was 310 feet by 38 feet by 24 feet and had a gross register tonnage of 3,400. During the next decade, the size of the Great Lakes bulk carriers increased and, in 1896, the 549-foot, 6,362-ton W. E. Casey was launched; she was the largest ship on the Lakes at that time.

The launching of a Great Lakes ore carrier was a sight to behold. Along the southern shores of Lake Erie, where most of the major shipyards were located, the lakeshore had too shallow a slope for the customary end launching and the rivers leading into the building yards were too narrow. From the earliest days of Great Lakes shipbuilding, the practice was to side-launch the ships into the rivers or even into the graving docks used for ship repair.

In a side launch, the launching ways, on which the ship slides, slope much more steeply than for an end launch and terminate above the water surface. This design allows the ship to accelerate to a high enough velocity to clear the end of the ways when it drops down into the water. In its travel, the ship heels far over and creates a tremendous wave along its length; it then rolls back and forth several times before coming to rest.

By the start of World War I in Europe, the largest bulk freighter on the Great Lakes was the steamer James J. Hill, with a gross register tonnage of 6,025 and a carrying capacity of 8,300 tons. By World War II, there were 153 steamers larger than the Hill with deadweight capacities ranging up to 15,000 tons, and five ore carriers of 18,600 tons capacity on a draft of 24 feet were under construction.

A new type of vessel for the carrying of limestone, used as a flux in the smelting of iron ore, was delivered in 1927. The Carl D. Bradley was similar to the ordinary bulk freighter in general construction. The hold, however, was of hopper form, the sides slanting to a longitudinal trough. On the deck was a large structural steel boom, which, at rest, extended fore and aft amidships, but, when loading, swung outboard over the pier. In the trough at the bottom of the hold there was a gravity-fed conveyor that carried the stone up to the boom, where it was weighed; another conveyor received it and deposited it on the wharf. This type of ship could off-load at piers where no equipment was installed for that purpose.

The Bradley was the largest self-unloader built to date with a length of 638 feet 9 inches, beam of 65 feet, and a depth of 33 feet. She had a deadweight capacity of 15,400 long tons at a draft of 22 feet 4 inches and could be off-loaded at a rate of 2,000 tons per hour. Her propelling machinery consisted of two watertube boilers and turbo-electric drive, furnishing 4,800 shaft horsepower to a single four-bladed propeller.

The first ore carriers for the Great Lakes to be equipped with marine turbines were the William A. Irwin, the Governor Miller, the Ralph H. Watson, and the John Hulst, in 1938. These vessels were very much alike. The first two used De Laval turbines and Foster Wheeler boilers; the other two, General Electric turbines and Babcock & Wilcox boilers.

The ships were 438 feet in the cargo hold, divided into three compartments. The principal dimensions of the vessels were as follows:

Length overall	610' 9"
Beam, molded	60' 0"
Depth, molded	32' 6"
Draft, summer freeboard	22' 1"
Displacement, F.W.	18,940 long tons
Cargo capacity	12,275 long tons

The loading time was short; usually two hours was sufficient if all conditions were favorable; unloading took four and one-half to five hours. These vessels made about 36 round trips per year, Duluth to Conneaut or to Chicago.

In 1941, new machinery was introduced for Great Lakes bulk freighters, namely, the Lentz poppet-valve steam engine. While this was new to the Lakes, it was well known in Europe. The economy of these engines for power below 3,000 indicated horsepower rivaled that of a turbine of the same power. As mentioned earlier, six of these engines were ordered by the Maritime Commission for Great Lakes ore carriers constructed during World War II.

Effects of Locks, Channels, and Weather on Great Lakes Commerce

The 20-foot drop in the St. Mary's River, connecting Lakes Superior and Huron, obstructed trade between Lake Superior and the lower lakes; the falls were passable only by portage. This barrier was broken in 1855 with the construction of the first lock at Sault Ste. Marie by the State of Michigan. There were two tandem locks, each 370 feet long, 70 feet in width at the top, 61 feet 6 inches at the bottom, the lift of each being 9 feet, and their depths 11 feet 6 inches.

The deepening of channels and the construction of large locks around the falls of Sault Ste. Marie permitted the building of larger steamers. By 1940, there were nearly one hundred bulk-freight vessels on the Great Lakes measuring 600 feet or more in length. In 1972, a 1,000-foot ship was delivered. The building of progressively larger locks and canalization of the St. Mary's River paralleled the rapid expansion of Great Lakes commerce. As part of the Soo Canal system between Lakes Superior and Huron:

-- the Weitzel lock, 515 feet long, 80 feet wide in the chamber, narrowing to 60 feet at the gates, and 17 feet deep was built by the United States in the years 1870 to 1881;

-- the Canadian canal and lock, the latter 900 feet long, 60 feet wide and 22 feet deep, was built during the years 1888 to 1895;

-- the Poe lock, built by the United States, 1887 to 1896, was 800 feet in length, 100 feet in width and 22 feet deep, its construction requiring the destruction, in 1888, of the original State locks;

-- the Davis and the Fourth (Sabin) locks, built by the United States, 1908 to 1919, are each 1,350 feet long, 80 feet wide and 24 feet 6 inches in depth, permitting simultaneous lockage of two 600-foot vessels;

-- the MacArthur lock completed by the United States in 1943 to replace the Weitzel lock, is 800 feet long and 80 feet wide.

Most recently, in 1962, the U. S. Army Corps of Engineers approved an increase in size of a new Poe lock at Sault Ste. Marie to 1,200 feet long by 110 feet wide with a depth over the sills at low water of 32 feet. Construction was started in 1964 and completed in 1970.

As with the Soo Canal, the Welland Canal between Lake Erie and Lake Ontario underwent frequent improvements as ship sizes increased. With Lake Erie at 573 feet above sea level and Lake Ontario at an elevation of 246 feet, the locks in the Welland Canal must accommodate a total drop of 327 feet. The original canal, opened in 1829, had 40 locks with a length of 110 feet and a depth over the sills of 8 feet. In 1841, the Canadian government bought out the Welland Canal Company and began an improvement program completed in 1845. This second Welland Canal had 27 locks, 150 feet long and 10 feet deep. The third Welland Canal, constructed between 1871 and 1887, had 26 locks that were 270 feet long, 45 feet wide, and 14 feet deep.

In 1913, Canada undertook another major improvement program on the Welland Canal, reducing the number of locks to eight, extending their width to 80 feet and their depth to 30 feet. The work was completed in 1932. The lock at the Lake Erie entrance is 1,350 feet long. The seven other locks range in length from 859 to 865 feet. Although the depth over the lock sills was increased in 1932 to 30 feet, the canal channel between locks had a depth of only 25 feet.

The Livingstone Canal, built in the lower reaches of the Detroit River, was finished in 1912. This channel, cut through limestone for about half of its 12-mile length, was originally 300 feet in width and 22 feet in depth. It was widened to 450 feet by 1925 to provide a downbound channel separate from that for upbound vessels. Prior to its construction, vessels navigated through a narrow, tortuous, and rock-bound section of the Detroit River.

Similar conditions in the St. Mary's River below Sault Ste. Marie were overcome with the construction of the West Neebish Channel, and, similarly, 5,000 feet of this channel was through solid rock. Completed in 1908, the channel was 13 miles long, 300 feet wide and 21 feet deep. Sixty-three years later, in the spring of 1971, the Corps of Engineers began a three-year project to widen six of the more restrictive bends in the St. Mary's River to accommodate the new 1,000-foot ships then under construction.

These improvements allowed the transit of larger vessels and improved coordination of loading and unloading facilities and ships. The larger cargoes and quicker turnaround resulted not only in the handling of much more traffic than could be handled by any reasonable increase in railroad facilities, but also in the marked reduction of carrier rates.

For many years, navigation on the Great Lakes was restricted to a season of 225 to 240 days, extending generally from the middle of April to the middle of November. During the winter months the connecting channels were icebound and, aside from a few car ferries and passenger boats operating in the open lakes, trade was suspended and vessels were laid up. In the late fall, most of the ships that carried grain from Duluth to the lower lakes grain elevators remained loaded through the winter layup to provide extra capacity for grain storage. The grain was then loaded into the elevators at the end of the winter season.

Winter navigation on the Great Lakes has, in fact, been a reality since before the turn of the nineteenth century, when icebreaking car ferries were placed into regular year-round service across Lake Michgan and in the Straits of Mackinac. Nevertheless, until the late 1960s, the most important units of the Great Lakes fleet--the bulk carriers--customarily confined their operating season to eight months of the year, at most.

In 1967-68, the managers of the U. S. Steel Corporation's Great Lakes fleet embarked on a prudently progressive year-by-year extension of the operating season. They were assisted in this by several federal agencies, all of which share with U. S. Steel the credit for the successful project results. The congressionally funded Winter Navigation Board, headed by the Corps of Engineers, and comprising several federal agencies and private interests, was charged with the demonstration program for season extension on the Great Lakes-St. Lawrence Seaway system. This board was responsible for demonstrating the engineering feasibility, and for defining the costs, economic benefits, and the social and environmental acceptability of extending the navigation season. On April 2, 1975, the locks of Sault Ste. Marie were opened for business as usual, and had been so for the previous 365 days. That seeming nonevent marked the successful achievement of what most had thought to be a far-fetched dream only months before: all-season shipping on the Lakes. Although the capability for all-season-shipping exists, it has not been utilized in recent years for economic reasons. Lowered steel production has reduced the annual requirement for ore. But, if steel production increases markedly in the future, the ore can be moved to the mills all year round.

Loading and Unloading Systems Speed Traffic

With the increasing size of the bulk freighters has come standardization adapted to the rapidly growing trade and designed to facilitate loading and unloading. The present freighter has hatches extending athwartships nearly the full breadth of the ship, with openings of 9 feet fore and aft, spaced on 12-foot centers, or 12 feet fore and aft, spaced on 24-foot centers. Thus, the deck, in preparation for receiving or discharging cargo, can be thrown almost completely open.

Loading and unloading facilities have kept pace with the growing demands of this highly specialized commerce. In the days of the steamer Hackett, the unloading of her 1,000-ton cargo took from three days to a week. Today, a 12,000-ton ore cargo is off-loaded, weighed, and put in the storage pile or loaded into railroad cars in a few hours. The original method of unloading ore, sand, coal, or other bulk commodities by buckets swung from the rigging, hoisted aloft by horses, dumped into wheelbarrows and wheeled ashore, has given way to elaborate and highly efficient machinery.

In 1880, a single-cable-wired rig was invented by Alexander E. Brown. It served the purpose of hoisting the bucket from the hold and conveying it to storage. This innovation, which revolutionized unloading methods, was installed on a dock at Cleveland in 1882, the plant consisting of five rigs with the machinery all in one house. Some years elapsed before the next improvement, the self-filling bucket or clamshell, became a part of the unloading equipment. The general features of this bucket were its great weight which enabled it to handle any grade of ore, its tremendous spread when open, and the peculiar movement of the blades when closing. It had a capacity of five tons of ore and a spread of 18 feet.

In 1899, George H. Hulett designed a machine which established new unloading records. A massive gantry, traveling on rails parallel to the wharf, supported a carriage that had a transverse at right angles to the face of the pier. This carriage, in turn, supported a tilting girder from which hung a vertical leg carrying a rotatable clamshell bucket.

Ore loading is accomplished by gravity. The loading piers consist of a series of pockets above which dump cars bringing the ore from the mines are run. Their loads are dumped into the pockets, each of which is provided with an adjustable chute. In loading, the chute is projected into the hold of the vessel and adjusted, as needed to direct the ore, for proper loading. The pockets and chutes are spaced in conformity with the hatch openings of the vessels so that any number of them may be dropped into the ship and operated at one time.

In grain handling, spouts project from the grain elevator into the cargo hold of the vessel. The grain is elevated from the bins in the elevator and runs by gravity through the spouts, which direct and distribute the grain so as to load the vessel evenly.

Unloading is, with slight variation, the reverse of loading. The leg of the elevator, in which there is an endless belt with metal buckets at short intervals, is placed in the hold. As long as this leg stands in deep grain, the latter feeds the buckets and is carried up into the elevator where it is placed in bins or directed into railroad cars.

When the new Poe lock opened at Sault Ste. Marie in 1970, the long awaited 1,000-foot Great Lakes ore carrier was finally feasible. One such design was the Stewart J. Cort, a diesel-powered self-unloader built by the Erie Marine Division of Litton Industries for Bethlehem Steel Corporation. The principal dimensions of this ship are:

Length, overall	1,000' 0"
Beam, overall	105' 0"
Depth	49' 0"
Draft	27' 10"
Shaft horsepower, normal . .	14,000
Speed (average)	16.5 mph
Deadweight	51,500 long tons

The bow and stern units for this unusual vessel were constructed at Ingalls Nuclear Shipbuilding in Pascagoula, Mississippi; the parallel middlebody, design for modular construction, was produced at Erie Marine in Erie, Pennsylvania. The cargo unloading rate is 20,000 long tons per hour. The vessel has twin screws and is also fitted with a pair of bow thrusters for improved maneuvering in restricted channels; these features appear frequently on ore carriers built since 1960. The Cort is ice-strengthened and capable of year-round operation.

Stewart J. Cort also has a unique iron-ore unloading system made possible by the advent of beneficiation and pelletizing. The system, designed by Hewitt-Robins, can handle an unloading rate varying from less than 6,000 up to 20,000 long tons per hour with a free-flowing material of one-half-inch lump size and below. It lessens cargo cubic loss in elevating the cargo from tank top to upper deck level; utilizes a minimum number of transition points and changes in flow direction (spillage problem areas); and requires fewer operating personnel, no tunnel gate operators, and less cleanup than has ever previously been possible.

Car Ferries Serve the Railroads

A large number of car ferries, most of which have twin screws, are in service on the Great Lakes. These ferries operate all winter, often in very bad weather, and try to meet the railroad schedules. Their sterns are open-ended and 30 to 34 freight cars can readily be backed in. The ferries also carry automobiles.

The Pere Marquette 17, built in 1900, was 350 feet long overall, 56 feet in the beam, and 19 feet 6 inches deep. Propulsion was by two triple-expansion engines, with cylinders 19, 31, and 52 inches diameter by 35 inches stroke; each engine developed 1,200 indicated horsepower. Steam was supplied at 175 pounds per square inch by four Scotch boilers.

It is interesting to note that between 1927 and 1942, the Pere Marquette fleet maintained uninterrupted service despite the fact that in the depth of winter these car ferries at times literally had to cut their way through fields of ice.

The City of Midland 41, built in 1941, has a 406-foot length, 58-foot beam, and accommodations for 376 passengers. She has a sea gate, which is in a raised position when receiving or discharging cargo.

This twin-screw vessel set a new standard for trans-lake passenger service. Operating at her ordinary speed of 18 miles an hour the ship made the 62-mile run between Ludington and Manitowoc in three and one-half hours. She could easily maintain, with ample time for lay-over at the piers, her summer schedule of two round trips daily. She was built with a specially designed bow to enable her to plow through ice, and operate year around. Her builders also installed two Erie-Skinner engines, each developing 3,500 horsepower at full power. They were the largest marine uniflow engines ever built. Each engine has five cylinders, 25 inches in diameter by 30 inches stroke.

Passenger Service on the Great Lakes

In covering the evolution of waterborne commerce, the employment of car ferries and other Lakes vessels as passenger carriers has been neglected. However, from the first trip of the Walk-in-the-Water until World War II, the need to carry passengers between Great Lakes ports also fostered major developments in ship design, construction, and operation.

Although cargo-carrying vessels on the Lakes shifted to screw propulsion in the late nineteenth century, paddle-wheel propulsion remained popular in passenger services. The last of the great side-wheelers were two passenger ships, the Greater Buffalo and the Greater Detroit, built by the American Shipbuilding Company of Cleveland, Ohio, for the Detroit and Cleveland Navigation Company. A first analysis of the intended service indicated the need for two vessels of about 560 feet, with about 800 staterooms each, and a maximum speed of 22 miles per hour. However, the use of twin screws with geared turbine or turbo-electric drive, which would be required to power ships of this size, appeared too costly for the expected revenue. Since the service was restricted to a four and one-half month operating season, the initial cost was an extremely important factor.

Another factor that led to the selection of paddle wheels was the restricted depth in Lake Erie. A draft limitation of 15 feet 6 inches would reduce the efficient utilization of large horsepower in screw propellers at that time. Also, the short, steep waves in Lake Erie could be expected to cause screw propellers to race frequently as the tips emerged from the water. As a result of the financial and engineering limitations, the two vessels were designed with paddle-wheel propulsion. The machinery used was adapted from the design of the Seeandbee, which had seen service on Lake Erie some years previously. With minor changes, the indicated horsepower of this machinery was raised from 9,000 to 10,500.

Using this machinery required the reduction of the intended length by some 30 feet and the number of passenger staterooms to 625. It was also decided that a speed of 21 miles per hour would be satisfactory. The final dimensions of the Greater Buffalo and Greater Detroit, as launched in 1924, were:

Length on waterline	530' 0"
Length overall	535' 0"
Beam, molded	58' 0"
Beam over guards	98' 0"
Depth to main deck	23' 0"

The passenger decks overhung the paddle wheels, thus creating a few problems in stability. However, the low center of gravity in the heavy engines helped increase the stability of the ship. The engines were three-cylinder, compound, inclined steam reciprocating engines with one 66-inch diameter high-pressure cylinder and two 96-inch diameter low-pressure cylinders. The stroke was nine feet.

The paddle wheels were of the feathering type with an overall diameter of 32 feet 5 inches and a blade-circle diameter of 25 feet 6 inches. The 11 blades were built with a slight curvature and were 14 feet 10 inches long and 5 feet wide. The blade dip was 7 feet 6 inches. On trial, these ships attained a speed of slightly over 21 miles per hour, with an indicated horsepower of about 12,000. The paddle wheels turned at a rate of 30 revolutions per minute. The propulsive coefficient was about 48.75 percent at maximum speed and about 50 percent at normal speed. The two ships carried passengers between Buffalo and Detroit for many years.

At the outbreak of World War II, the Navy had an urgent requirement for training pilots in carrier landings and takeoffs. The lack of combat ships for training purposes led Navy officials to look for other craft. The Greater Buffalo and the Greater Detroit were particularly adaptable to this purpose. The wide, overhanging passenger deck provided sufficient area for conversion to a flight deck, the speed of 21 miles per hour was sufficient for the low-speed training aircraft, and the paddle wheels on either side made the vessels very maneuverable. After conversion to aircraft carriers, the ships were renamed Wolverine and Sable. They performed yeoman service in qualifying Navy pilots, and are probably the only aircraft carriers ever to be driven by the paddle wheel.

Effect of Opening the St. Lawrence Seaway

From the Gulf of St. Lawrence to Montreal, a distance of 528 miles, the St. Lawrence River has, because of improvements made by the Canadian government, had sufficient depth for seagoing ships for many years. However, from Montreal to Ogdensburg, New York, where elevation changes 224 feet in about 120 miles, a series of canals and locks were required to bypass falls and rapids. Between Ogdensburg and Lake Ontario, a distance of 62 miles, the change in elevation is less than three feet, and this part of the river could accommodate deep-draft ships.

By 1903, the Canadian government had installed 21 locks and 14-foot-deep canals between Montreal and Ogdensburg. The World War I ships built on the Great Lakes were designed with a length overall of 261 feet and a maximum beam of 43 feet 9 inches, the greatest dimensions that could be accommodated in the Welland Canal and the canals between Ogdensburg and Montreal, i.e., the Galops, Rapide du Plat, Farran's Point, Cornwall, Soulanges, and Lachine Canals. Despite continuing improvements, the same limitations prevailed in World War II with the Lachine Locks being the controlling factor.

The St. Lawrence Seaway Development Corporation was created by an act of Congress in 1954 which called for American-Canadian cooperation in developing a 27-foot channel from Lake Erie to the Atlantic Ocean. The final design provided seven locks that would lift vessels 227 feet in the 183 miles between Montreal and Lake Ontario. The locks were to have a usable length of 776 feet, a width of 80 feet, and a depth of 30 feet over the sills. The St. Lawrence Seaway was finally opened for deep-draft vessels on April 25, 1959.

The first full operating season of the St. Lawrence Seaway was from April through September 1959. In this first year, the Port of Toledo increased its import/export trade 277 percent over 1958. Cleveland reported a 200 percent increase, and exports of grain from Duluth/Superior went from 650,000 bushels in 1958 to 86,000,000 bushels in 1959; this latter figure was expected to double in 1960.

Volkswagen of America contributed its share toward building up the business of the St. Lawrence Seaway. The company fleet closed its 1962 Lakes season with the delivery of 250 VW sedans to Toledo. That delivery brought to 27,811 the total VW cars, trucks, and station wagons unloaded at Great Lakes ports in the 1962 season, compared with 20,649 units during 1961.

American flag ship operators were singing a different tune. American Export Lines estimated a $500,000 loss on its Great Lakes operations; Grace Line also reported a loss. Costly delays in ports and long voyages were some of the reported causes. However, the shipping lines soon began adapting their ships and operations to this new market.

The launching of the Mormacpride in early 1960 was part of the Moore McCormack Line's ship replacement program. Built by Sun, this vessel, along with six sister ships then under construction, was equipped with two rubbing bars on each side to withstand the narrow locking through the Seaway. Universal mooring chocks and special provisions on cargo winches were installed for locking operations. A sewage disposal system was installed to prevent freshwater harbor contamination. These ships were each 466 feet by 68 feet by 38 feet and had a gross register tonnage of 9,308. In August 1981, Moore McCormack initiated its U. S. flag Lakes' service, operating between Great Lakes ports and the east coast of South America and South and East Africa, as well as on the U. S. North Atlantic/Scandinavia and Baltic trade routes.

In September 1961, the Moran Towing Company received permission to operate through the St. Lawrence Seaway and the New York State Barge Canal. The company began operations on its new route by towing two 211-foot barges, the Wallace and the Stillman, plus a new 231-foot container barge. The planned route extended from the Atlantic coast up the Hudson River to Troy, New York, through the New York State Barge Canal to Oswego, then, via Lake Ontario and the Welland Canal, to Lake Erie and other points on the Lakes.

In 1961, between Montreal and Lake Ontario, the downbound traffic from April through September showed a 31 percent increase over 1960, which was offset by a 15 percent decrease in upbound loads. The 1961 total was 16.6 million tons; 15.1 million was recorded for 1960. The Welland Canal traffic remained practically the same as 1960 with a slight increase from 22.2 million to 22.4 million tons. Total vessel transits were 5,069 through the Montreal-Lake Ontario section and 5,569 through the Welland Canal. By the 1964 season, total traffic through the Montreal-Lake Ontario section was more than 29 million tons; the Welland Canal accommodated 35,305,000 tons of bulk cargo and 2,104,000 of general cargo. These totals are steadily increasing each year.

In 1959, the total U. S. waterborne commerce on the Great Lakes was 166.7 million tons, of which 131.2 million were domestic and 35.5 million were foreign. The Great Lakes' share of the total waterborne commerce of the United States was 15.84 percent in that year, comprising 18.05 percent of the domestic trade and 10.90 percent of the foreign trade.

By 1968, the U. S. waterborne commerce on the Great Lakes was 151.1 million tons domestic and 62.5 million foreign for a total of 213.6 million. The Great Lakes' share had increased to 17.02 percent of the U. S. domestic trade total, but its share of the foreign trade total was up to 12.31 percent for approximately the same average of 15.30 percent of the total U. S. waterborne commerce.

Between 1959 and 1977, the foreign trade of the Great Lakes area increased from 35.5 to 69.2 million tons; the domestic trade grew from 131.2 million tons in 1959 to a peak of 164 million tons in 1968 and then decreased to 116.7 million tons in 1977. Thus, the foreign trade as a percentage of the Great Lakes total increased steadily, about 0.84 percent per year, in this nineteen-year period--from 21.3 to 37.2 percent.

These statistics show that the waterborne commerce of the Great Lakes is a significant part of the United States total and that the St. Lawrence Seaway has been an important factor in opening up a new avenue of foreign trade with the Great Lakes area.

Chapter 7

COMMERCIAL VESSELS ON THE INLAND WATERWAYS

When explorers reached the shores of America, they continued inland as far as their sailing ships could conveniently carry them. Where harbors and rivers shoaled, river currents increased, or there was insufficient wind, they ceased their exploration by ship. So it was also with the early settlers. Initially, they encamped where they found safe, protected landfalls that were within easy range of their marine transportation in order to maintain lines of communication and supply, and to beat a hasty retreat if necessary.

Once the settlements close to the sea became established bases, explorers and settlers worked their way farther inland, looking for more productive areas for self-enrichment and to provide for the ever-expanding population. As in the Great Lakes area, the most efficient mode of transportation was the primitive canoe of the American Indian.

However, special vessels were devised to meet unique transportation requirements in the areas surrounding major settlements on the eastern seaboard. In the 1720s, a group of Philadelphians built a blast furnace on Scooks Creek off the Delaware in a location where ore and limestone were available, together with wood to produce charcoal. A water-wheel-powered bellows was used to raise the furnace temperature to melt the ore and the molten iron ran out into hoed trenches which formed it into pigs. To get these to market, Robert Durham, the ironmaster, devised a boat patterned after the Lenape dugout. It was some 60 feet by 8 feet by 42 inches. With a 15-ton load of pig iron, the boat drew 28 inches of water. The boat could be poled down the creek, shooting the rapids, guided by a 33-foot-long sweep at the stern. After reaching the tidewater region below Trenton, the boat was rowed to the customer's dock in Philadelphia. These Durham boats were copied for use on other rivers: the Mohawk, the St. Lawrence, and as far away as the Fox River in Wisconsin.

The fur trade was the driving force behind exploration of inland lakes and rivers. Canoes could be paddled upriver in a reasonably light condition and portaged around rapids and falls. On the return run, downstream, the loaded canoes rode with the current, with portage required only around the most severe drops in the river. Many of these canoes had places for fourteen paddlers and were capable of carrying several thousand pounds of freight.

In addition to the gradual westward movement from the East Coast, explorers, following La Salle, made their way down the Mississippi from the north. Meanwhile, other adventurers from the east crossed the Alleghenies and found rivers running west and south. In 1742, John Howard conducted a major exploration of the Ohio and Mississippi valleys by drifting down the Ohio and the Mississippi to New Orleans.

River Transportation Before Steam

By 1768, the westward migration had begun and, as the rivers, particularly the Ohio, offered suitable access, there arose a demand for a waterborne "carryall." The solution was found in the flatboat.

As a rule, the flatboats were rectangular scows. Usually they were completely boarded on all sides from deck to roof, although some builders contented themselves with a half deckhouse and a half open deck. In its capacity as a family mover, the flatboat accommodated the owner, his wife, their children, and cattle. If sufficient adult males were available, progress was helped along with "sweeps." Steering was done with a long oar at the stern. Sand bars and riffles were negotiated by means of a cordelle--a reel-like device on the boat that wound a hawser made fast to a tree on the bank and pulled the boat over the obstacle. Unable to return upstream, the flatboats were broken up at journey's end and frequently provided the materials for the family's dwelling.

To meet the demand for a boat that could move upstream, the keelboat evolved. It had a keel and frames like a ship. The deckhouse was set in from the gunwale, leaving a walkway. Progress upstream was made by six to eighteen men with poles, who walked to the bow, stuck the poles into the river bed and then walked slowly aft, pushing. These boats were from 30 to 75 feet long, and, until the arrival of steam, they were the only practical upstream vessels on the inland waters. Sails were also used when feasible.

Arks, batteaux, and skiffs were variations of these two fundamental designs, made to suit the tastes or requirements of the users. Batteaux were built by both the French and the British to transport troops. From these beginnings, the first packet service evolved in 1794, using galley-type keelboats, 75 to 100 feet long, carrying passengers and freight and making the round trip from Pittsburgh to Cincinnati in one month.

These craft continued to operate for many decades, but on a diminishing scale. Flatboats evolved into freight carriers with trained, river-wise crews that returned from the downstream voyage overland. They descended the rivers at the rate of 3,000 trips a year between

1810 and 1820, and continued in use as coal carriers until after the Civil War. The pilots who handled these floating cargoes became the pioneer steamboat captains.

Introduction of Steam Propulsion

That part of the Ohio River between Wheeling and Pittsburgh was the area where the bulk of flatboats and keelboats were built and lumber, nails, machine shops, and experienced builders were available. It is not surprising, therefore, that the first steamboat used on inland rivers was built near Pittsburgh and started on its maiden voyage from that port.

Steamers had been tried in the Delaware, and the Clermont had made the first practical run in the Hudson, in 1807, but the inland rivers did not hear the hiss of steam until four years later. Then, Nicholas Roosevelt, representing the Fulton interests, built the New Orleans and descended to New Orleans in her, over a route he had surveyed from a deluxe flatboat in 1809. Curiously enough, the details of the New Orleans were not preserved, and no one knows her dimensions, the specifications of her engines, or, indeed, whether she was a side- or stern-wheeler. The best guess is that she was 138 feet long and had a 26-foot beam, with a low-pressure vertical engine.

When the centennial of her trip was celebrated in 1911, Captain James A. Henderson of Pittsburgh constructed a "replica." For this purpose, he selected the side-wheel design, but the point has never conclusively been settled.

Stern wheel or side wheel, the New Orleans ushered in a new era of riverboat design. Numerous experimental steamers were built as soon as the New Orleans had turned in a satisfactory performance.

The first steamers followed tidewater designs, with comparatively deep-draft hulls. Captain Henry M. Shreve made an important advance with his G. Washington, built in 1816. This boat seems to have been the first shallow-draft steamer. Captain Shreve saw a river steamboat hull as a buoyancy chamber, rather than a space for engines and cargo. The G. Washington had her engines on the first deck. Her engines were high pressure with stationary horizontal cylinders, a departure from the favorite design of Fulton, and a cornerstone for future riverboat construction.

Minimum weight was the prime requisite. For that reason boiler pressures ranged from 80 to 130 pounds until the arrival of steel boiler plate in 1880. The famed Robert E. Lee that raced the Natchez in 1870 was allowed 120 pounds. In tidewater streams where channels were deep, weight was not such a factor. Hudson River builders of this period used 30 and 40 pounds, with boilers of great dimensions and cylinders of large diameter, and produced the "racehorses" of their day, capable of 22 or 23 miles an hour.

Western steamboats met shallow-draft requirements with boiler shells of small diameter, boosted to the greatest pressure obtainable. This practice was most effective in keeping hull weights and operating draft at a minimum. The hulls were built so light and flimsy that five years usually wore them out, if snagging, ice, fire, or a boiler explosion had not destroyed them before usage and warping made further operation unsafe.

The fuel arrangements in the early steamboat period were somewhat unusual. The original New Orleans started from Pittsburgh burning bituminous coal and began burning wood when coal was no longer available. Succeeding steamboats also burned the fuel most readily at hand, which meant that boats near Pittsburgh used coal and boats farther down the Ohio, on the Mississippi, and other tributary streams used wood. The early Cincinnati packet boats burned coal and wood--about one-third coal and two-thirds wood. Beechwood was obtained, if possible, as rivermen recognized that it made the hottest fire and lasted longer in the furnaces. The use of wood as fuel declined as shipments of coal south increased, but the Missouri River packets burned wood until the 1880s.

Low-pressure engines were attempted during the 1830s but the weight factor and the sediment problem caused their abandonment. As a rule, more than the allowable steam pressures were carried on the inland riverboats; in fact, it was not unusual for a hook to be built on the lever of the safety valve, so that grate bars and the like could be attached in order to build up excess steam. Grimly enough, engineers called this the "death hook."

The so-called "western river boiler" appeared soon after steamboats began to ply the rivers. This was a horizontal cylinder, at first provided with a single flue. In 1835, there were boats with batteries of six and seven such boilers, all connected and fitted with cast-iron mud-drum legs and copper steam lines. The frequency of explosion was due, perhaps, more to faulty materials than poor engineering. Up to 1840, the boiler plate used was made by laminating thin sheets of iron, usually five in number. These were rolled at the mill. There was no method for testing the strength of the laminations. After an explosion, fragments of the boilers sometimes resembled the pages of a torn book. The feedwater for the boilers was supplied by a pump worked by a cam on the wheel shafts. When the wheels were stopped, the water supply stopped. Many explosions occurred just as a boat was backing from a landing, after laying dormant awhile--and the reason is not hard to fathom; independent feedwater pumps did not arrive until 1850.

In spite of the design handicaps and material deficiencies that marked the early days of inland river steamboating, the economic effect was to reassure eastern financiers that the potentialities of the river valleys could be realized. Commercial activity greatly increased.

Eastern interests began to push through the feeders that were to provide freight and passenger loads to tax every bottom on the rivers before 1832. The National Pike opened in 1816. The roads terminating at or near Pittsburgh were enlarged and still groaned under their loads. The Bedford-Lancaster Pike accommodated 12,000 wagons (mostly Conestoga type) in 1817. Canals were being planned for Ohio and Pennsylvania, the former to be opened in 1832, the latter in 1835. Immigrants began to pour westward and steamboat building and operation expanded to meet this growing need for passenger and freight transportation.

Captain Shreve's basic shallow-draft design now began to make its own value felt. Such boats could land anywhere on the sloping river banks, except, of course, at high bluffs. Steamboats began to nose up tributary streams, capturing business previously handled by flatboats and keelboats. The Great Kanawha had been opened to steamers in 1823. The Allegheny was navigated by a steamer to Franklin in 1828 and to Olean, New York, in 1829. The Cumberland saw steam navigation in 1832. In that same year the Missouri was navigated by a steamer, appropriately named Yellowstone, clear to the mouth of the Yellowstone River. The Monongahela, Muskingum, Kentucky, and Green rivers were explored by steamers in 1836.

Economic Impact of Inland River Commerce

The inland waters of the United States owe much of their development to the steam-driven paddle-wheeler. The Mississippi, Missouri, Ohio, and Monongahela rivers, although wide, were shallow and tortuous. The paddle wheel was ideally suited for this type of waterway. It adapted itself readily to installation in a flat-bottomed, shallow draft boat and required a minimum of immersion. Damaged blades could be replaced easily by inexperienced carpenters, and the power plant required to drive it was an uncomplicated, simply maintained set of machinery.

Following the successful employment of the steamboat New Orleans for the trade between New Orleans and Natchez, many larger and more powerful steamboats were built and put into service all along the midwestern rivers. Some of the famous steamboats were: Enterprise, Washington, Shelby, Paragon, Tecumseh, Tuscarora, General Brown, Randolph, Empress, Sultana, Edward Shippen, Belle of the West, Duke of Orleans, Bostona, Belle Key, Reindeer, Eclipse, and A. L. Shotwell. In 1818, the United States Mail Line was organized for both cargo and passenger service between Cincinnati, Louisville, and St. Louis. Tonnages increased from 75 to the 2,000 ton Grand Republic built in 1867; by 1858, a maximum speed of 20 miles per hour had been obtained. A few side-wheelers and stern-wheelers can still be seen in operation on the inland waters of this country.

The American river steamboats were beautiful things to behold. Sharp bows and long, clean lines allowed them to cut through the water with minimum disturbance of the surface. They were, for the most part, narrow boats with length-to-beam ratios of 12 or more. Their huge paddle wheels were the pride of their owners and passengers. The New World, which plied the Hudson River, had wheels 46 feet in diameter. Those of the Alida were 31 feet 6 inches, and the Thomas Powell, a smaller boat by far, boasted wheels of 40 feet in diameter. Speaking of the American river steamboat, the designer of the Great Eastern, John Scott Russell, said, " . . . they stand in every respect--in science, in speed, in beauty, in magnitude--unparalleled by the river steamers of Britain, or those of any other country." (The Modern System of Naval Architecture, London, 1865.)

Canals and Canal Boats

Canal development in the United States began in the early 1790s. These early canals were relatively unimportant, however, and construction became significant only when attempts were made to provide access from the seaport regions to the undeveloped interior west of the Allegheny Mountains. Several major waterway projects were planned to connect eastern seaports with the interior, providing low-cost water transportation into the heart of the country while developing particular seaports as the natural outlet for the inland commerce that was expected to result. The most celebrated of these projects were the Chesapeake and Ohio Canal, to link Georgetown, now a section of Washington, D. C., and the Ohio River; the Pennsylvania Main Line Canal, a combined canal and railroad system designed to link Philadelphia and Pittsburgh; and the Erie Canal between the Hudson River and the Great Lakes.

The idea for a waterway connecting the Potomac River and the Ohio River originated as early as 1774. After a series of abortive attempts, construction on a canal up the Potomac Valley to Cumberland was begun in 1828. Progress was slow and the canal did not reach

Cumberland until about 1850. No connection with the Ohio River was ever accomplished and the canal never served as a traffic channel for the commerce of the midwest to reach the merchants of Georgetown.

A second ambitious attempt to connect the eastern seaboard and the midwest was the Pennsylvania Main Line Canal. This transportation system included a rail line from Philadelphia to Columbia on the Susquehanna River, a distance of 81.6 miles; the eastern portion of the Pennsylvania Canal westward from the Susquehanna for 172 miles; a portage railroad 37 miles in length across the summit of the Alleghenies; and finally a western section of the Pennsylvania Canal from Johnstown to Pittsburgh, a distance of some 104 miles. With its other branches, the complete system totalled some 606 miles. The canal portion of the transportation project was four feet deep and had a width of 28 feet at the bottom of the channels. The locks were 90 feet long and varied between 15 and 17 feet in depth.

By far the most significant of the early American canals was the Erie Canal between Albany on the Hudson River and Buffalo on Lake Erie. This canal followed the water level route westward and avoided the difficult mountain terrain. It had an average width of 40 feet and a depth of four feet; its locks were 15 feet wide. Once the canal reached the Great Lakes, an inland area of tremendous proportions was immediately opened up for settlement and the development of commerce. As a result, the Erie Canal proved to be a conspicuous financial success at a time when many of the other canals were encountering financial difficulties.

The Erie Canal was completed in 1825 and very quickly developed a tremendous business. When the canal was completed, there were still no railroads in the United States and construction of any significance was still quite a few years away. As a result, the canal furnished a transportation facility that was far more economical than any existing alternative. The natural result was to funnel trade from the Great Lakes region to the East through the waterway and, likewise, to send shipments westward over the same route.

While the Erie Canal was the most significant of the early canals, there were others of some importance constructed in the interior of the United States, notably the Louisville and Portland Canal, built between 1826 and 1831, which enabled Ohio River boats to pass the falls of the Ohio.

Canal boats, hauled by mules walking along a towpath, were extremely simple structures. Since they traveled at only three to four miles an hour, there was no particular reason to shape the hull in an effort to lower resistance. The usual configuration was a double-ender with a full formed deck curving into the stem and stern so as to take advantage of the extra length that could be fitted into the triangular closure of the lock gates at the upper end of the lock. The beam was usually slightly less than the lock width and the depth was one or two feet greater than the maximum draft that the canal depth would allow; thus, a freeboard of one or two feet was customary.

An interesting point about canal barge draft was raised by Benjamin Franklin in 1768 when he was living in London and had made a trip through some of the canals in Holland. In a letter to Sir John Pringle, he noted that when the water in the canals was low, it was much more difficult for the horse pulling the boat and tended to slow down. Franklin correctly analyzed this shallow-water effect as being due to the greater relative water velocity along the hull as the water displaced at the bow was forced through a narrow space between the hull and the canal bottom; this in turn caused an increased drag on the hull.

After returning to England, Franklin fabricated a small model testing basin with an adjustable bottom. Using a six-inch-long model boat drawn by a gravity dynamometer, he measured the time of travel down the basin for different water depths and clearly proved his theories. As he correctly pointed out, the problem applies to all confined waterways; in modern times, it particularly applies in the case of a powerful tug pushing a fleet of barges upstream against a heavy current. A "bank" effect, corresponding to this "bottom" effect, can also cause problems with ships or barges passing each other when travelling in opposite directions on a waterway; maneuvering can be affected by bank suction or a hydrodynamic attraction between the passing vessels.

As steam power replaced sail at sea and on the Lakes, the horse-hauled canal boats gradually gave way to self-propelled ones and steam tugs hauling barges. Similarly, steel replaced wooden hulls. The first fleet of steel canal boats on the Erie Canal was constructed in 1895 and consisted of a steamer and five consorts, all being 98 feet long, 17 feet 10 inches wide, and 10 feet deep. The steamer, driven by a fore and aft compound engine of 120 horsepower, carried 125 tons of freight, while the consorts carried 230 tons each. The first trip was made in August 1895, with a cargo of rails for the New York street railways. On the return trip, they carried sugar to Cleveland for local distribution and for transfer by rail to other cities; one train left Cleveland with 36 cars of sugar.

In January 1896, additions to this steel fleet were contracted for, three steamers and ten consorts. They were the same breadth and length as the first ones, but designed two feet deeper to fully utilize an increased depth of two feet of water in the canal. Each steamer had a tandem compound engine with diameters of 12 and 24 inches, a

16-inch stroke, and a Roberts tubular boiler. These engines developed about 275 horsepower. The consorts were built with square bilges, and open-hearth steel was used in the construction. The steamers had rounded bilges, but with about the same general construction as the barges.

The vessels were run in fleets of one steamer and three consorts, carrying in all about 1,000 tons. Four fleets were kept constantly en route, with each steamer dropping her three consorts in New York, and picking up three others already loaded for the return trip. The dropped consorts were loaded for the next steamer. A reduction of expense of about 40 percent was effected by the use of steam as compared with horse towing. The greatly increased fleet ordered after the first season's experience was evidence of the commercial success of the venture; the system saved shippers at least 25 percent of the rail rate. A fleet made about five miles an hour in Lake Erie, and from three and one-half to four miles on the canal; the trip from Cleveland to New York took about ten days.

With the improvement of the New York state canals, authorized by a referendum in 1903, the system became popularly known as the Barge Canal. The four branches improved were: (1) the Erie, or main canal, which stretches across the state from east to west and joins the Hudson River and Lake Erie; (2) the Oswego, which connects that city on the southeast shore of Lake Ontario with Erie; (3) the Cayuga and Seneca, which leaves the Erie a little to the west of the Oswego junction and extends south, first to Cayuga Lake and then to Seneca Lake; and (4) the Champlain which runs north from the Hudson to Lake Champlain.

The dimensions of the Barge Canal are the same for all four branches. Briefly, in the independent or artificial canal, the minimum channel cut in earth is 75 feet wide at bottom and 123 to 271 feet at water-surface. In rock cutting, with nearly vertical sides, the width is 94 feet. In river and lake channels the width is from 150 to 200 feet. There is a depth of 12 feet throughout. Although the actual dimensions varied greatly, the minimum size was fixed by law. The locks had uniform horizontal dimensions. Chambers, from lower gates to upper breast wall were 310 feet long and 45 feet wide. Rules adopted for navigating the canal system limited the size of barges to 300 by 42 feet. There were no fixed bridges over the channel less than 15 feet 6 inches above water level at the highest navigable stage.

In 1935, the federal government budgeted for the enlargement of about 184 miles of canal, of which 160 were in the Erie Canal from Waterford to Three Rivers Point, and 24 were in the Oswego Canal from Three Rivers Point to Oswego. The improvement included deepening between locks to 14 feet; widening at bends and elsewhere; increasing the overhead clearance to 20 feet at bridges; and providing channel widths of 104 feet in earth cuts, 120 in rock cuts, and 200 in river sections. This federal improvement is known as the Great Lakes to Hudson River Waterway.

The Passenger Packet

The 1830s produced the era of the passenger packet, a period of dazzling brilliance and intense and interesting activity. Passenger packets began to dominate the rivers in 1836, a year in which 107 steamboats were launched in the Mississippi Valley system. They continued their sway unopposed until the railroads came west in the 1850s, and then staged a comeback after the Civil War. In appearance and conveniences, the passenger packet of this time often outshone the ocean steamships then in service.

As their name suggests, these packets were supported largely by the passenger trade. Freight was carried, of course, but a great tide of European emigration--sweeping westward--and the swelling business enterprises of the region supplied a seemingly inexhaustible stream of passengers; it was for their trade that the boats competed.

Passenger packets were not, as a rule, through boats, as from Pittsburgh to New Orleans. They ran in "trade routes" or "lines"--Pittsburgh to Cincinnati, Louisville to New Orleans, Cincinnati to St. Louis, etc. Even the original river steamer New Orleans was, after her maiden trip, in trade service between Natchez and New Orleans.

The early packets, designed before 1860, had excessively slender hull lines for high-speed operation. These slim racers were also considerably overpowered with the width across the battery of boilers often exceeding the width of the hull. This led to a dangerous lack of stability and, on some packets, deckhands were called upon to move wagons loaded with chain across the deck to check the heel as the ship rounded a turn. This slender-hull design trend ended during the 1850s, but many time records set during that period have not, to this day, been equalled. For a comparison, note the hull dimensions of the Eclipse, built in 1852, 363 feet long and 36-foot beam, and the Grand Republic, built in 1867, 335 feet long and 51-foot beam.

The first J. M. White exemplified the design for speed practiced before 1850. Built in 1844 at Elizabeth, Pennsylvania, she was 250 feet long by 31-foot beam with an 8½-foot hold. Seven boilers supplied steam to engines whose cylinders were 31 inches in diameter with a 10-foot stroke. The chief feature of her design was that the side wheels were placed well aft, giving a better "bite" on her bow wave.

She set a record from Pittsburgh to Cincinnati (468 miles) of 24 hours and 5 minutes. Her run from New Orleans to St. Louis in 3 days, 23 hours and 9 minutes was not beaten until 1870.

A post-war J. M. White was a packet built in 1878 with graceful lines but a much broader beam than her namesake; the deck extended well beyond the waterline to provide carrying space for cotton bales. Her engines had cylinders 43 inches in diameter with an 11-foot stroke.

The first experiments with iron hulls occurred in 1839, when the Valley Forge, a packet with a hull of sligo iron, was built in Pittsburgh. She was soon dismantled; her dimensions, 165 feet by 25 feet by 5½ feet, were too small to be commercially practical. Metal hulls were regarded as expensive, and most boats of the nineteenth century were of wood, which was readily available and for which skilled workmen could easily be had.

An excellent example of passenger-packet design in which both speed and elegance were used as bait for customers was the Eclipse built in 1852 at New Albany, Indiana. She was 363 feet long, 36-foot beam and 9-foot hold, carrying two engines with 36-inch cylinders and 11-foot stroke, fed by eight boilers each 32½ feet long and 26 inches in diameter. She had paddle wheels 41 feet in diameter. In elegance, her cabin gleamed with gilt and paintings. She had 48 bridal chambers, staterooms for scores of passengers, and sleeping quarters for servants. At that time there were few seagoing vessels of her size and elegance in the world. In speed, her record run was from New Orleans to Louisville in 1853, when she made the distance in 4 days, 9 hours and 21 minutes.

With the Eclipse, packet-building reached its zenith. Engine-room techniques had advanced with the use of boiler feed pumps, and propelling engines were equipped with cut-off, slides, balances, and piston or poppet valves. Standards of excellence extended to reliable operations; schedules were well maintained all along the river, navigating conditions having been favorable 10½ months out of the year for more than a decade. Warehouses burst with goods and docks swarmed with passengers. The future must have looked rosy indeed to the rivermen of that period.

Barges and Towboat Transportation Systems

Great controversies raged between river and railroad interests during the period of railroad expansion. Economically, the rails had presented a challenge that the rivers had to meet by readjusting their facilities so as to carry the bulky cargoes that remain their primary means of profitable operation. This adjustment was long and painful, but it brought forth the towboat in its early form, the fleet of barges and scenes of activity that bore some relation to those seen on the rivers today.

Barges had been lashed to steamboats as early as 1832, and, in 1854, the Crescent City was built and operated expressly as a towboat for barges. But it was not until the seventies that fleets of barges became a common sight. The growing use of crude oil, which was found in locations convenient to river transportation, had a part in this development.

As iron and steel production became great industries, the movement of coal increased in importance. The coal trade had, for years, consigned its wares to coal boats that were in some respects similar to the old flatboats. They were controlled, or steered, by sweeps and the boats were too flimsy and cheap to warrant their return upstream. The increasing importance of coal to industry called for larger and more regular deliveries and a foundation was laid for a waterborne coal transportation system that today carries the largest single item of inland river tonnage. And, the length of the trip gradually shortened as coal-consuming industries sprang up in ever-increasing numbers closer to the coal-producing area near Pittsburgh.

In 1885, the first Ohio River navigation dam was opened at Davis Island, five miles below Pittsburgh. The balance of the river was unimproved, except for the canal past the falls of the Ohio at Louisville which had been enlarged to accommodate the growing size of riverboats.

As the Ohio descends 420 feet from its source at Pittsburgh to its mouth at Cairo, there was a tendency for the river to "run off" during dry spells, and the necessary nine-foot channel to accommodate profitable fleets of coal boats was not always available. In fact, the coal boats habitually waited in the slack-water pools near Pittsburgh for a suitable boating stage. When this stage occurred, two or three times a year, there was a mad scramble to cast off, and a line of towboats and coal containers, frequently a hundred miles long, headed down the rivers, many of the loads going as far as New Orleans.

Powerful towboats were needed to overcome this condition. They had to be capable of handling upward of 30,000 tons on the downstream trip and returning the empty carriers, which were, by now, wooden barges of crude but sturdy construction. As designers attacked this problem they had to consider a number of factors, the prime one being that of propulsion.

Side-wheelers had been the favored boats of the packet era. But packets had only to handle their own length, and did not have to maneuver a fleet of barges. The towboats would have to push and guide downstream loads, which, without the river current, they hardly could have moved. For this work, the stern wheel seemed most adaptable.

The Ajax, built in 1865, took 16,000 tons of coal to New Orleans in 1868. The John A. Wood, the first large compound-engine towboat built specifically for the heavy downstream river coal trade, had engines with an 18-inch high-pressure cylinder, a 41-inch low-pressure cylinder, and an 8-foot stroke. Built in 1870, she was successful, and many others of similar design followed.

The super-towboats reached their peak in 1902, with the building at Dubuque, Iowa, of the Sprague. The early feats of this boat are legendary. In February 1907, she took a huge flotilla of 56 coal boats and six barges from Louisville to New Orleans. Resembling a floating island, the flotilla measured 925 feet long by 312 feet wide, covered seven acres, and carried 67,307 tons of coal, a record which stands to this day. The Sprague had a steel hull to withstand the stresses set up by pushing heavy tonnage. She measured 276 feet by 61 feet by 7 feet 5 inches. .Her compound engines were 26s-63s with a 12-foot stroke. A stern-wheeler, she had a wheel 40 feet in diameter with buckets (paddles) 40 feet long.

A detailed analysis and experimental study of the most efficient means of moving cargo on the inland waterways of the United States was authorized by the River and Harbor Act of 1910. The act stated in part:

"The Chief of Engineers, under the direction of the Secretary of War, is hereby authorized to design and construct two experimental towboats of modern but different types, with a complement of suitable barges and necessary loading and unloading facilities for towing and delivering supplies along the Mississippi River and its tributaries, and in making designs for such boats the said Chief of Engineers shall investigate and consider types of boats in use for similar purposes on nontidal rivers in this and other countries, and for the purposes of such investigation, designs, and construction there is hereby appropriated the sum of $500,000."

The Board on Experimental Towboats, which the Chief of Engineers established to carry out these instructions, issued its report in February 1914. The board investigated current river towing practices in the United States and abroad, and conducted lengthy model tests in the Naval Tank at the University of Michigan to determine the resistance of barges and flotillas and the propulsive and towing characteristics of various types of towboats. It concluded:

" . . . that the two towboats be of the stern-wheel type and the twin-screw tunnel type, with beam of 43 feet and 34 feet, respectively, length between perpendiculars 170 feet, and draft 4 feet in both cases . . . that the stern-wheel boat be provided with a feathering wheel . . . that its boilers be of the internally fired, return-tube type with straight tubes . . . that its engines be of the tandem compound condensing or similar type . . ."

The model tests indicated that the feathering paddle wheel should be 14.6 feet in diameter and should be driven by a 1,200 IHP engine at a speed of 25.6 revolutions per minute. The predicted slip was 62.6 percent, and the predicted efficiency of the wheel was 29 percent.

This exhanstive report by a competent group of authorities forcefully indicates the status of transportation on the inland rivers of the United States just prior to World War I. It was a transition era when the channels of the navigable rivers would gradually be deepened to accommodate deeper tows. This meant that the more efficient screw propeller could be used, provided that hull modifications were made to encompass a larger-diameter propeller than that used in earlier towboats. However, conditions were such that the paddle-wheel towboat was still in a strongly competitive position. for river use.

Waterways Improvements

In 1922, Congress passed an appropriation of $42 million to improve navigation on the Ohio, where it was certain that economies of transportation would benefit the nation. Just prior to this time, the government had set up the Federal Barge Line to stimulate a revival of river-borne commerce competition on the Mississippi. The Carnegie Steel Company responded and formed a river transportation department and began operations. Forerunners of the modern common-carrier barge line appeared. Canalization promised dependable stages with a channel deep enough to make payloads profitable.

The improvement was finished on schedule. In October 1929, the chain of 53 locks and dams (since reduced to 20 by the installation of several high-lift dams) extending from Pittsburgh to Cairo was dedicated.

The effect was felt at once. New barge lines were organized to carry tows from Pittsburgh to all navigable points on the inland river system. Extended coal movements, involving transshipping by rail in many cases, were restored. Petroleum and acids began to move on the rivers in the new steel barges designed and built to handle such cargoes. Standard open hopper barges began to carry pipe and other steel products south, and to return with scrap, sulphur, and fluorspar.

On the heels of the Ohio River improvement came a similar canalization program on the upper Mississippi between St. Louis and Minneapolis. Twenty-six modern locks were built to assure continuous navigation for that 700-mile stretch. The Missouri was straightened and dredged to allow light-draft hulls to travel as far as Sioux City, 760 miles from its mouth. Between 1875 and 1899, the Kanawha River, connecting the West Virginia coal fields to the Ohio, had nine locks and dams; improvements have now reduced this to two high-lift locks. Other tributary streams have been improved as well.

In 1900, the Chicago Sanitary and Ship Canal was built to carry sewage and cargo from Chicago, through the Des Plaines and Illinois rivers, to the Mississippi. This opened up a permanent connection between Lake Michigan and the Gulf of Mexico that was to be useful in moving ships and submarines built on the Great Lakes out to salt water during World War II. In addition, the Intracoastal Canal and the Tennessee River project have added to the scope of the inland waterways that cover so much of the United States between the Alleghenies and the western plains.

Modern Inland Waterway Commerce

Since the opening of the canalized rivers, the experiments carried on during 1910-1920 have borne fruit. Steel barges, with streamlined rakes, lessened resistance so that horsepower requirements are from 45 to 60 percent below those of their more cumbersome predecessors. Barge types have been improved; weather-proof covered barges now protect cargoes; tank barges carry all manner of liquids; and the merchandise carriers, like huge floating boxcars, are frequently seen. Barge sizes have been standardized according to service, thus maximizing use of the space available in the lock chambers that must be passed through on the scheduled run.

For boat designers working in the period since the 1930s, two sources of power, steam and diesel, and two methods of propulsion, stern wheel and screw propeller, were available. In that decade, construction of modern river towboats included four basic combinations of these elements: (1) steam stern-wheel, (2) steam screw-propeller, (3) diesel stern-wheel and (4) diesel screw-propeller.

Steam stern-wheelers of improved design were best typified by the Jason, a powerful boat capable of handling the huge tows that were characteristic of the common-carrier service in the 1930s. Her boilers were fired with oil, and her tandem-compound engines were the piston and poppet-valve type, 16s-32s with a 10-foot stroke. Her wheel was 25 feet in diameter. She could back and flank with tows of 15,000 tons, 915 feet in length. While conditions are bound to vary somewhat with general-merchandise tows transversing the length of the Ohio and Mississippi rivers, it was nevertheless true that the Jason's operating costs ran from 25 to 30 percent above screw-propelled diesel towboats in the same service.

Steamboats with screw propellers found some favor. One example of this type was the Ohio, built in the early 1930s. She was 200 feet by 40 feet by 10 feet 6 inches, twin-screw, and powered with two vertical uniflow condensing three-cylinder single-expansion engines and rated 2,000 horsepower at 135 revolutions per minute. She was modernized in 1939 by the reconfiguration of the stern and the installation of Kort nozzles. The improvement in earning capacity based on a ton-mile performance was said to be 25 percent due to the Kort nozzle installation.

Diesel stern-wheelers were developed and in use; a speed-reducing gear compensated for the high revolutions per minute of the diesel engine and the low revolutions per minute of the stern wheel. The majority of these boats were designed for shallow-draft operation before the nine-foot channel made screw propellers more practical.

The most popular of the 1930s towboat designs was the diesel-powered, screw-propelled boat. It has been noted that, in the growth of river barge commerce, the stern-wheel boat superseded the side-wheel one because of the improved steering and flanking qualities obtained by having the paddle wheel as far aft as possible to provide for suitable rudder installations. In that period, the greater bulk of traffic was downstream. Under these conditions, stern-wheel boats could handle immense tows. They were appreciably aided by the river current, and required only enough power to control the loaded tow on a downstream voyage and to return the empty containers upstream.

With the canalization of the Ohio River, upstream traffic began to grow. Petroleum, scrap, sulphur, fluorspar, and other bulk commodities were consigned to a river that had become a dependable avenue of traffic. Pushing loaded barges upriver, however, required a towboat with greater powering and control. Rivermen gave their attention to designs that departed from traditional river practice and led to experiments with diesel power and screw propulsion. Boats so equipped were found to have greater fuel economy and were better able to proceed against the current with appreciable loads. Between 1940 and 1942, over 80 new diesel boats entered service in the Mississippi Valley. During that same time, only three or four steamboats were built.

An important development in towboat design was the adoption of the Kort nozzle. Invented by Ludwig Kort in 1936 to increase towing ability, it is essentially a cylindrical housing enshrouding the

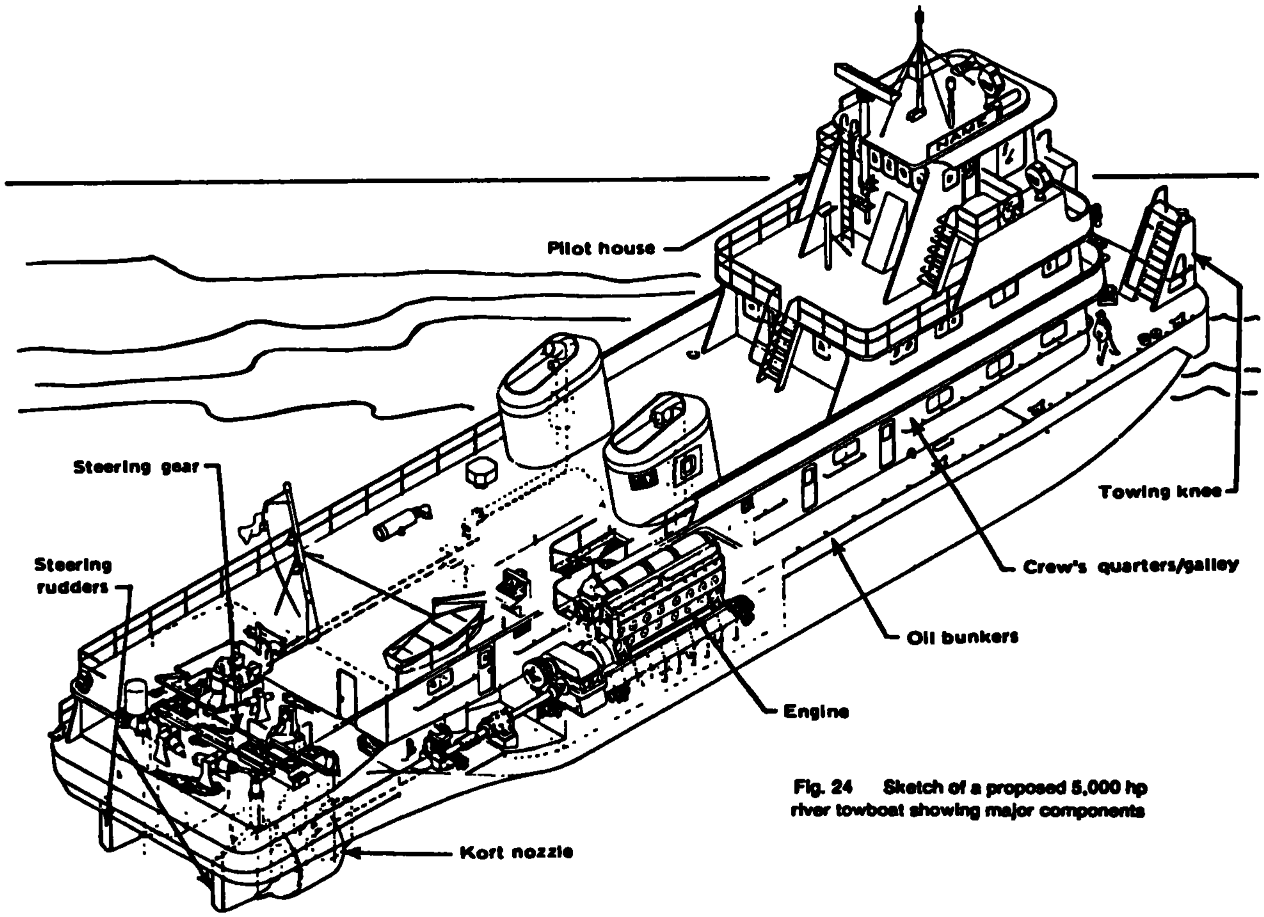


Fig. 24 Sketch of a proposed 5,000 hp river towboat showing major components

propeller. It guides the water to, and accelerates the flow through, the propeller. Its installation permits the addition of more tonnage to the flotilla, or the use of a towboat with 15 to 30 percent less rated horsepower on any given towing assignment.

Generally speaking, a screw propeller can be made more efficient by increasing its diameter and decreasing its rotational speed. However, with the present nine-foot draft limitation on the upper rivers, the propeller diameter is limited since the propeller cannot extend below the hull without certain damage. One solution, used on towboats for many years, is to cut a tunnel into the hull in way of the propeller so that the inflow water has an unrestricted path into the propeller disc.

In some cases, the top of the tunnel, and thus the top of the propeller blades, is actually above the surrounding waterline. As the boat gets underway, the flow of water forced through the tunnel, rises above the outside water level so that the propeller operates submerged despite the fact that the blade tips are above the waterline. This has certain disadvantages, particularly when reversing, because the entrainment of air in the propellers causes loss of thrust.

One advantage of the Kort nozzle is that upwards of half of the total thrust is developed by the nozzle itself, thus the propeller is less heavily loaded. For the same total thrust, a nozzle propeller can be of considerably less diameter than an open one of the same horsepower and it turns at a higher RPM.

The towboats operating on the Mississippi River system have, in recent years, increased dramatically in size, power, and tow-handling capability. One of the largest of the modern towboats, also named Jason, is 190 feet in length, with a 54-foot beam and a 12-foot 6-inch depth. Operating at a draft of 9 feet, her three 3,500 horsepower diesels allow her to handle tows of up to 50,000 short tons against the current.

Barge dimensions have been standardized to fit the 600 by 110 feet dimensions of the locks. One standard barge size is 195 by 35 feet with a draft of 9; a three-by-three tow can be locked through in one operation. If the towboat is less than 195 feet long, a 15-barge tow can be accommodated in two locking operations: nine barges are run in for the first, followed by six more and the towboat in the second. Other towboats are used for removing the first nine barges from the lock. A number of the locks in the Mississippi system have been lengthened to 1,200 feet to permit tows of this size to move through in a single locking operation.

The barges are designed for minimum resistance in fleet operations. There are bow-unit barges with a raked end forward and a squared-off end aft; center-unit barges with both ends squared-off; and stern-unit barges with squared-off forward ends and raked sterns. It is not always possible to assemble large tows with the most efficient combination of units, but, in general, these massive ones move up and down the rivers with apparent ease, and totally under control of the towboat pilot.

Chapter 8

RECENT DEVELOPMENTS OF VESSELS FOR SPECIFIC MISSIONS

During World War II, the United States spent over sixteen billion dollars on merchant ship construction. Some 5,600 ships, totalling more than 56 million tons, were constructed in American shipyards. When it became evident that World War II was approaching a victorious conclusion, the Maritime Commission initiated plans to dispose of about 4,000 government-owned merchant ships. Under the terms of the Merchant Ship Sales Act of 1946, which expired in 1948, more than 1,100 of these ships were sold for foreign registry. Those remaining fulfilled the twin objectives of a merchant marine for commerce and defense for the time being.

The recovery of European shipping was strongly encouraged, in part to reduce the burden imposed on the U. S. economy. Yet, by the end of the Korean conflict, foreign competition had gained sufficient strength to force operators of U. S. privately-owned tramp ships to lay them up for lack of cargoes; by mid-1954, only 51 percent remained in service.

Although the Merchant Marine Act of 1936 laid the ground work for a modern merchant marine, the balance of ship types in the resultant fleet did not give a competitive edge over foreign fleets. Compounding the problem, postwar reliance on World War II ships, and various conversions of these vessels, produced an aging fleet, falling behind in speed, efficiency, and carrying capacity.

In 1950, Reorganization Plan 21 abolished the Maritime Commission as an independent agency and transferred the jurisdiction of maritime affairs to the Maritime Administration, an agency of the Department of Commerce as had been its ancestor, the U. S. Shipping Board. The tie to Commerce was strengthened by the Merchant Marine Act of 1970 which designated the Maritime Administrator as the Assistant Secretary for Maritime Affairs. In August 1981, the Maritime Administration was transferred to the Department of Transportation.

In 1969, the President sent to Congress strong proposals for maritime legislation that would enable American flag ships to carry an increasing share of U. S. foreign trade at competitive world prices. These proposals were enacted into law as the Merchant Marine Act of 1970. During the next four years, the largest peacetime shipbuilding program, totalling 8.8 million deadweight tons, got underway resulting in technologically advanced ships, designed for specific missions and cargoes.

General Cargo Ships

The general cargo ship is so designated because of its ability to carry different commodities in a variety of forms such as sacked, boxed, palletized, refrigerated, and containerized. It may also have accommodation for bulk materials, such as grain, in designated holds and special oils in tank compartments.

Cargo liner is the designation given to those general cargo ships engaged in international trade between specific ports and on regular schedules. Their cargo mix is fairly well established as to type and quantity. Additionally, cargo space allocations, along with optimum hatch sizes and appropriate handling gear can be satisfactorily determined to meet the specified trade requirements.

The general-purpose cargo ship (more commonly called the tramp ship) is the designation given to a general breakbulk that has no set trade route or schedule, but plies between ports all over the world, following the dictates of each particular consignment. Its economic justification lies in its ability to handle and deliver cargoes of unusual size and/or to service ports not normally attended by the cargo liner. To these ends, the modern tramp ship is frequently equipped with heavy-lift cargo gear, in addition to its normal cargo gear, to handle lifts of 100 tons or more. She may also have at least one extra-long hold and hatch for cargo of exceptional dimensions. Because high speed is not a requisite in this trade, the ship is fuller and of less installed power than a comparable cargo liner.

A standard design for a general cargo ship attempts to embody the major features of size, speed, and capability that are representative of a particular vessel type and service, whether it be liner or tramp ship. Perhaps the most exemplary standard cargo ship of recent design has been the Mariner, developed by the Maritime Administration in its program to rejuvenate the entire U. S. Merchant Marine. Over fifty of these vessels were constructed throughout the 1950s and 1960s, in a number of shipyards, and for numerous owners.

There have been no significant changes in the basic range of general cargo ship size and speed in recent years. With a few notable exceptions, ship lengths have remained in the 450- to 550-foot range, with displacements of from 15,000 to 25,000 tons. Speeds for cargo liners are still around 20 knots; for tramp ships about 16 knots.

Both have variations of several knots either way, depending on the service requirements envisioned.

The deadweight capacity of the cargo liners through this range of ship sizes is within a narrow band of 12,000 to 15,000 tons; for the tramp ship, or special-cargo carrier, it is about 15,000 to 20,000 tons. Speed is a controlling factor in ship design and the consequent variety of ship types necessary to accomplish the basic purpose of cargo transport.

Container and Barge Carrying Ships

A general cargo ship designed to carry all of its cargo in unitized containers is designated as a full containership. Prior to the 1960s, containers had been carried to some extent--on deck or in selected holds as part of the cargo mix on typical general cargo ships. But, it required the technological breakthrough of the all-hatch concept to provide full and effective stowage of containers throughout the vessel, and to make the containership a practical reality.

Containers come in a number of standard sizes, and all are basically selected to allow their use as trailer-truck bodies or to be carried on railroad flat cars for the overland portions of their total voyage. The concept, originating in the United States, of an intermodal carrier that could quickly and efficiently transport a valuable cargo, usually door-to-door, with a minimum of handling, captured the imagination of the transportation industry in the highly developed countries of Europe and, later, and Japan. The containership became the darling of the shipping world; and the United States enjoyed a pivotal position in most of this trade.

The containerships of the early 1960s were little different in principal characteristics from the standard cargo ship of the time. With the rapid increase in demand for containerized transports, design requirements for high capacity and greater speed were mandated, and shortly led to ships of double the previous capacity and speeds up to 33 knots, exceptional in cargo ships. In hardly more than a decade, the containership has largely lost resemblance to the general cargo ship, in characteristics, if not in function, and, in fact, today rivals the bygone passenger liner in size, sleekness, and speed.

The full containership embodies the concept of full cellular stowage within the holds, plumbing directly down through a multiple array of hatches, in a guided arrangement to secure the containers, without dunnage, against shifting while at sea. Additionally, most containerships are designed to carry containers on deck, stacked three to four high and secured by systems of lashing, to afford sufficient deadweight carrying capacity for what is normally a high-cubic, low-weight cargo system. In order to protect the exposed cargo against the forces of the sea, particularly when green seas are taken over the bow, a high forecastle is provided, along with a well-flared bow shape. Additionally, the bridgehouse and quarters are located forward, which further provides for better visibility, without encumbrance from the container stack. Principal characteristics of a typical containership, the American Lancer, are given below.

Length	670' 0"
Beam	80' 0"
Depth	50' 6"
Draft	27' 10"
Speed	21.5 knots
Propulsion	Steam
No. of equivalent 20-foot container units, TEUs . . .	1,178
Shaft horsepower	27,300
Deadweight	22,275 tons
Displacement	32,000 tons

The barge-carrying ship is essentially a containership, the major difference being that its containers are barges, larger than the standard container, and handled to and from the water instead of the pier. For example, the standard 20-foot container has a cubic capacity of approximately 1,200 cubic feet; the standard LASH lighter, a capacity of 20,000 cubic feet, and the standard SEABEE barge, a capacity of 40,000 cubic feet.

Those differences, however, make the barge carrier highly competitive in many trading areas throughout the world. In heavily industrialized port areas, particularly those associated with a developed river transport system, there is a great convenience and economy in having full bargeloads of commodity move directly to waterfront plants or to remote terminals upriver for discharge and further inland distribution. In less developed, or antiquated, port areas throughout the world, where commerce is heavy, but where facilities are inadequate for rapid cargo handling, warehousing, or distribution, barge-contained cargoes can more readily be accommodated and dispatched. And, in all major port areas, delays of several days to several weeks often confront cargo vessels awaiting dock-side space for loading or unloading. The barge-carrying ship avoids any such delay, it can handle its cargo in the open roadsteads or at anchor in the harbor.

The basic barge-carrier configuration is essentially dictated by the method in which the barges are handled on and off the vessel.

In the SEABEE class, barges are floated into position at the stern of the ship and lifted by powered means to a designated deck elevation, and then trolleyed forward into the ship's hold or upper deck. There are three deck levels including the main deck to accommodate the barges, in a sort of sliding file arrangement, aft to forward. There are, necessarily, no transverse bulkheads through the cargo area, and the arrangement lends itself ideally to the alternate carrying of roll-on/roll-off cargo.

In the LASH ships, barges are lifted at the stern by a deck-mounted gantry crane, which travels forward and deposits them into deep hold cells. The barges are specially designed to stack one above the other on corner posts built into their structure. Full transverse bulkheads at traditional spacing are provided, and, because of the large hatch openings, main deck structure is limited to the side areas. Alternately, the ship can serve as a containership, in part or fully, with the addition of a container crane.

Dimensions of these ships are given below.

SHIPS	LASH	SEABEE
Length, overall	893' 4"	875' 11"
Length, between perpendiculars	797' 4"	740' 0"
Beam, maximum	100' 0"	105' 10"
Depth, amidships	60' 0"	74' 10"
Draft, load	31' 0"	39' 0"
Speed	20 knots	18.6 knots
Shaft horsepower	32,000	36,000
Propulsion	Steam	Steam
Number of barges	89	38
Deadweight, tons	46,153	38,410
Displacement, tons	62,314	57,290

BARGES	LASH	SEABEE
Length, overall	61' 6"	97' 6"
Beam, maximum	31' 2"	35' 0"
Depth	13' 0"	15' 10"
Draft	8' 8"	10' 6"
Deadweight, tons	369.6	833.9
Displacement, tons	455.4	1,000.0

Roll-On/Roll-Off Ships

The roll-on/roll-off (ro/ro) was the forerunner of the full containership by nearly a decade, embodying the concept of transporting trailers, complete with undercarriage; thus, the name trailership was alternately used for this type of vessel. Rapid handling of cargo on and off the vessel, in the form of wheeled vehicles, by means of stern or bow ramps and even sideports (for smaller vehicles) was, of course, a well-established practice before this time. The novel feature of the ro/ro was in the adaptation to a high-speed, transoceanic system featuring multi-deck ships--an adaptation in response to the era's increasing demand for rapid international movement of high-premium containerized cargo.

The inherent disadvantage of the full trailership, on an equivalent cargo basis, is the waste of cubic capacity required for undercarriage and all-around clearances. Even when tailored to standard containers moved in on low-slung dollies, affording some 40 percent increase in cargo capacity, it cannot meet the carrying capacity of the full containership with its more efficient vertical modular stowage.

During the containership surge, the ro/ro diminished in popularity. Its use continued, however, and the technology involved advanced. And, today, it has evolved to the point of perhaps being the most favored high-speed cargo vessel. The current, popular, type is a combination carrier. Its upper deck and perhaps some selected holds are dedicated to containers as a significant portion of the cargo. The remaining lower decks are assigned to wheeled vehicles ranging from trailers to minicars, as the traffic dictates. Provision may also be made for carrying general cargo, incorporating the usual hold/hatch/cargo gear or simply forklift.

Thus, the roll-on/roll-off ship of today is no longer the full trailership as conceived over two decades ago. It retains the name ro/ro to designate that it features the use of loading ramps for wheeled vehicles, even in instances where the major cargo may be of other containment.

The most prevalent arrangement of the present-day large trans-ocean ro/ro consigns most of the below-deck cargo space to wheeled vehicles and/or to general cargo that is wheeled into place by dolly or forklift through the loading ramps. Internal ramps lead from the loading deck to the other 'tween-deck spaces. In some foreign designs, the entire ship's length, from the stern to the forward quarter of the vessel, is devoid of transverse bulkheads. In order for ships of this type to qualify for American registry, full-depth transverse bulkheads, equipped with mechanically operated watertight doors closing off the large access openings, need to be installed.

Typically, the combination ro/ro ship of today has the same dead-weight capacity, speed, and power as the general cargo ship that would otherwise be used in parallel service. However, because its cargoes are usually low-density, the ship is roughly ten percent larger in length, beam, and depth, resulting in a lower draft and significantly higher freeboard than the comparable general cargo ship.

Tankers and Other Bulk Carriers

The history of tanker design and construction through the years since World War II has been highlighted by a progressive increase in size and power--from the general standard of about 25,000-ton deadweight capacity in the 1940s, to 50,000 in the mid-fifties. Many of these larger tankers were enlarged versions of the wartime T2s with parallel middlebody added between bow and stern sections. The size of tankers continued to increase rapidly in the following years through the 100,000-ton deadweight range and continued to the point where the largest vessels in history are tankers of over one-half million deadweight tons. Installed power also increased, from the range of 13,000 shaft horsepower to over 50,000 in the largest vessels.

The United States did not participate to any significant degree in this trend to large tanker construction for three basic reasons. First, and foremost, the available shipyard facilities were not adequate to construct such large ships and the investment required to provide such facilities could not be justified by the anticipated profits. Second, building expenses for such vessels in the United States were not competitive with foreign costs and government subsidies were not forthcoming to make up the difference. Finally, there were few American ports that could accommodate ships in the supertanker category; none of these were on the East or Gulf coasts and the few West Coast ports with adequate depth were reluctant to provide the necessary facilities.

As of November 1, 1973, the world orderbook included 549 tankers over 150,000 deadweight tons; of these, 23 were under 200,000; 473 were between 200,000 and 400,000; 53 were over 400,000 including six tankers between 500,000 and 550,000 and one of 706,000. Seatrain, Incorporated, at the old Brooklyn Navy Yard, was building 225,000-ton tankers for the trade from Valdez, Alaska to the West Coast, and Bethlehem Steel Corporation had expanded its facilities at Sparrows Point to build 265,000-ton deadweight tankers. It was then expected that American shipbuilders would, by 1978, have the capacity to build super ocean-going carriers with capacities up to 600,000 deadweight tons.

Much of the planned expansion was based on a continuing increase in the worldwide demand for oil and the anticipated construction of offshore oil terminals in Texas, Louisiana, and Alabama. But, when the bubble of anticipation burst, the construction boom ended with only the Seatrain and the Bethlehem tankers being constructed. The

Seatrain ships are delivering oil from Alaska to a large storage tanker anchored off Panama where the cargo is transferred to smaller tankers that can transit the Canal and deliver it to the East Coast. The Bethlehem tankers are either laid up or are employed in trade routes that do not include the United States.

Although the picture is bleak there has been some recent progress toward expansion of America's capacity to receive imported oil from the very-large- and ultra-large-crude carriers, VLCCs and ULCCs. Despite several false starts, one of the planned Gulf Coast tanker ports is now in operation. On May 4, 1981, the 270,015-ton deadweight tanker Texas Caribbean carefully maneuvered to tie up to the Single Anchor Leg Mooring (SALM) buoy 19 miles off the Louisiana coast at the new Louisiana Offshore Oil Port (LOOP) system. The present LOOP system can handle imports of 1.4 million barrels of oil per day with planned capacity increases to 2.4 million and then 3.4 million barrels per day. This system now connects with more than 25 percent of the nation's refining capacity.

The variation in characteristics with ship size is indicated in the table below which compares a 40,000-, an 80,000-, and a 390,000-ton deadweight tanker.

	Products Carrier	San Clemente Class Tanker	VLCC Tanker
Length, overall	688' 6"	892' 6"	1187' 6"
Beam, maximum	90' 0"	105' 9"	228' 0"
Depth, amidships	47' 0"	62' 6"	95' 0"
Draft, full load	35' 0"	45' 0"	74' 0"
Gross tonnage, U. S.	22,358 tons	43,000 tons	-
Net tonnage, U. S.	15,951 tons	37,000 tons	-
Lightship weight	7,569 tons	18,710 tons	60,140 tons
Deadweight	40,760 tons	80,500 tons	390,770 tons
Full load displacement	47,329 tons	99,210 tons	450,910 tons
Shaft horsepower	15,000	24,000	45,000
Sea speed	16.0 knots	16.5 knots	15.9 knots

Aside from the fact that the large tankers of today are bigger in all dimensions than their predecessors, there have been significant changes in ship proportions. Length to beam ratios are now typically 5.5 to 5.6, where previously they were in the 7.5 range. Similarly, length to draft ratios have been reduced to under 16 (except for the specifically designed shallow-draft tankers) where the previous range was 18 and over. With design speed requirements remaining essentially constant through the years, less proportionate increases in length could be adopted without penalty in operating economy. The net effect has been a reduction in steel weight ratio and a resulting increase in deadweight capacity, from the earlier range of 0.75 of total displacement to 0.80-0.85.

Distinct from the liquid bulk carrier, or tanker, is the dry bulk carrier, the general designation for those vessels primarily intended to carry dry cargo loaded with no containment other than that of the ship's hold. Dry bulk cargoes vary in nature and specific gravity, from iron ore to grains, and vessel proportions, internal arrangements, and structure are strongly influenced by the specific cargo to be carried, in addition to the usual logistic and economic constraints.

Bulk carriers engaged in international trade are most frequently intended to be combination carriers, with one principal commodity carried on the outbound leg of the voyage and a different one inbound. Such cargoes may be dry bulk both ways (ore and grain, for example), or dry bulk to liquid (coal and oil). In the latter case, which is prevalent in today's worldwide trade, the carrier is generally designated as an Ore/Bulk/Oil Carrier (OBO).

Bulk carriers have shown a growth pattern through the years parallel to that of tankers, and are, in fact, practically identical in hull form and proportions and power for a given cargo deadweight. The principal differences in configuration are in the incorporation of large hatches in the main deck leading into the dry-bulk compartments, and in the shape and arrangement of the hold compartments themselves. The compartments of a pure tanker are relatively simple in pattern, with vertical transverse and longitudinal bulkheads from deck to bottom shell resulting in a rectangular, egg-crate arrangement. Those of the bulker may be slope-sided, octagonal shaped, extending to the hull sides as one transverse compartment, or relatively small in section with large wing tanks. In any given ship, the design is suited to the cargo requirements--density, handling methods, comparative quantities of the various cargoes intended, in the most effective manner under the constraints imposed for the particular service.

Liquefied Natural Gas (LNG) Tankers

Liquefied natural gas was first transported at sea in 1959, and became commercially practical in 1964. Complex technical considerations are involved in carrying flammable liquid cargo at a temperature of about -260°F.

However, the rate of growth in ship size has been phenomenal beginning with the 5,000-cubic-meter Methane Pioneer in 1959, and leaping to the 27,400-cubic-meter Methane Princess in 1964, and to the 125,000-cubic-meter El Paso Kayser in 1975. Designs of up to 300,000 cubic meters have been prepared and given basic acceptance by classification societies.

Due to the extremely low density of the cargo, such large ships have relatively light full-load drafts and can be accommodated in channels at numerous ports. Perhaps one of their greatest problems is the extremely high freeboard, which results in high wind loading.

In addition to rapid growth in size, inventors have devised a plethora of containment systems to serve as tanks to hold the LNG. With the applicability of NASA space technology in cryogenics, new systems are still being developed and will probably replace some of the existing systems. Presently, the systems installed by U. S. shipyards building LNG tankers are the Kvaerner-Moss spherical, the Conch free-standing prismatic, or the Technigaz membrane tanks.

These vessels are of shallow draft relative to their beam, because of the low density of the cargo and the ships' high centers of gravity. And, because of the shallow drafts involved, the maximum acceptable power on a single screw is about 45,000 horsepower. This required careful design and analysis of the lines and propeller, and imposes a speed limitation of about 20 knots on larger ships (21 knots trial speed). At least one design utilizes twin-screw propulsion to achieve a sea speed of 23 knots.

Seagoing Tug/Barge Systems

The term tug/barge has generally been adopted to describe push towing at sea, whereby the tug is positioned at the stern of the barge and provides positive control of thrust and steering through rigid or semi-rigid structural attachment. Its inland waterways counterpart is the typical push tow employed in relatively calm water, where the square bow of the towboat is simply snubbed up to the barge stern and secured by a relatively elastic wire rope system. The seagoing tug/ barge must be configured so that there is no damage due to bumping from surge differences, or grinding due to relative transverse, vertical, or rotational motions of the two units under wave action.

Present tug/barge configurations include the linkage arrangement such as Sea-Link, which attaches the tug to the barge stern, clear of contact with it, through a structural framework. The linkage is such that the tug and barge act together in the three horizontal modes of surge, sway, and yaw; differential roll is partially restrained, but there is freedom to allow independent motions of pitch and heave.

Other arrangements such as Artubar include trunnion mountings, which are extended from both sides of the tug's hull and socketed into wing wall extensions of the barge, allowing no relative motion between the tug and barge with the exception of pitch. In this case, the tug is reasonably nested within the barges sides but with sufficient clearance to allow free pitching.

In another arrangement, the tug is completely nested into the barge recess. A twin-hull tug such as the Catug, capable of straddling a tongue extension of the barge, is used. The tug is fully restrained in all directions, so that it effectively forms a complete ship in all major respects.

From a hydrodynamic standpoint, the tug/barge has a distinct powering advantage over the conventional configuration of a barge being pulled by a tugboat--the push tug operates in the barge wake with reduced resistance and higher propulsive efficiency. In pull-towing, the tugboat has its own high resistance to overcome, as well as that of the barge and any appended barge skegs needed for course-keeping stability in this configuration.

At present, the tug/barge under the U. S. flag may operate with the normal tug complement instead of roughly twice that number required for a ship of the same size and power. This is a distinct advantage in manning. From the standpoint of logistics, the linkage-type tug/barge is most suitable for shuttle service of relatively short voyages where loaded barges are swapped for empties, paralleling inland river practice. The locked-in, nested tug/barge is specifically designed for longer ocean voyages. Essentially remaining married in service, it competes directly with seagoing ships on the basis of smaller crews and less initial construction cost.

A Base for Future Expansion

The ships described here, and many other types not mentioned, are the well-equipped components of a modern merchant marine plying the essential foreign trade routes of the United States; to these can be added the ore, coal, and grain fleets of the Great Lakes and the modern towboats and barge fleets that work throughout the inland waterway system. Supporting these waterborne commerce carriers are well-equipped shipbuilding and repair yards dispersed along the Atlantic, Gulf, and Pacific coasts, and the shores of the Great Lakes and inland waterways. There is a strong educational base for providing the essential technically trained manpower to design, build, and operate these ships and other vessels. There is a comprehensive technological base with ongoing research in almost all facets of shipbuilding, ship operations, and marine technology. And, finally, there is a strong cadre of capable merchant seafarers, lakers, and rivermen. Collectively, these current assets of the United States provide a substantial base for the expansion of our waterborne commerce in the years to come.

Since the country's early beginnings, from colonial days to the present, American ship designers, builders, and mariners have demonstrated their ability not only to equal but to outperform their contemporaries throughout the world. Whenever there has been an obvious challenge to be met, a profit to be made, or an enemy to be driven from the seas, the maritime industry of the United States has performed magnificently. Unfortunately, as a nation, America allows itself to fall behind the rest of the world's maritime powers in times of peace and only in times of war are its superior capabilities demonstrated. Although our technological innovations continue in peacetime, their benefits more often accrue to other nations than to ourselves. Only with the full support of the American people, reflected in a strong and consistent maritime policy, can the downward trend in the volume of waterborne commerce carried in American ships be reversed. Such a policy is vital to the best interests of the nation.

GLOSSARY OF TERMS

ABAFT. Aft of; toward the stern from a designated location.

ADZ. A cutting tool, resembling a pick, with a thin arched blade set at right angles to the handle.

AFT. Toward, at, or near the stern.

AFTERBODY. That portion of a ship's hull abaft amidships.

AFTERPEAK. The compartment in the stern, abaft the aftermost watertight bulkhead.

AFTER PERPENDICULAR. See LENGTH BETWEEN PERPENDICULARS.

AMERICAN FLAG SHIP. A ship that sails under United States registry.

AMIDSHIPS. In the vinicity of the midlength of a ship as distinguished from the ends. Technically it is exactly halfway between forward and the after perpendiculars.

ANCHOR. A heavy forging or casting so shaped as to grip the sea bottom, and, by means of a cable or rope, hold a ship or other floating structure in a desired position regardless of wind and current.

APPENDAGES. The portions of a vessel extending beyond the main hull such as rudder, shafting, struts, bossings, and bilge keels.

ATHWARTSHIP. Across the ship, at right angles to the fore-and-aft centerline.

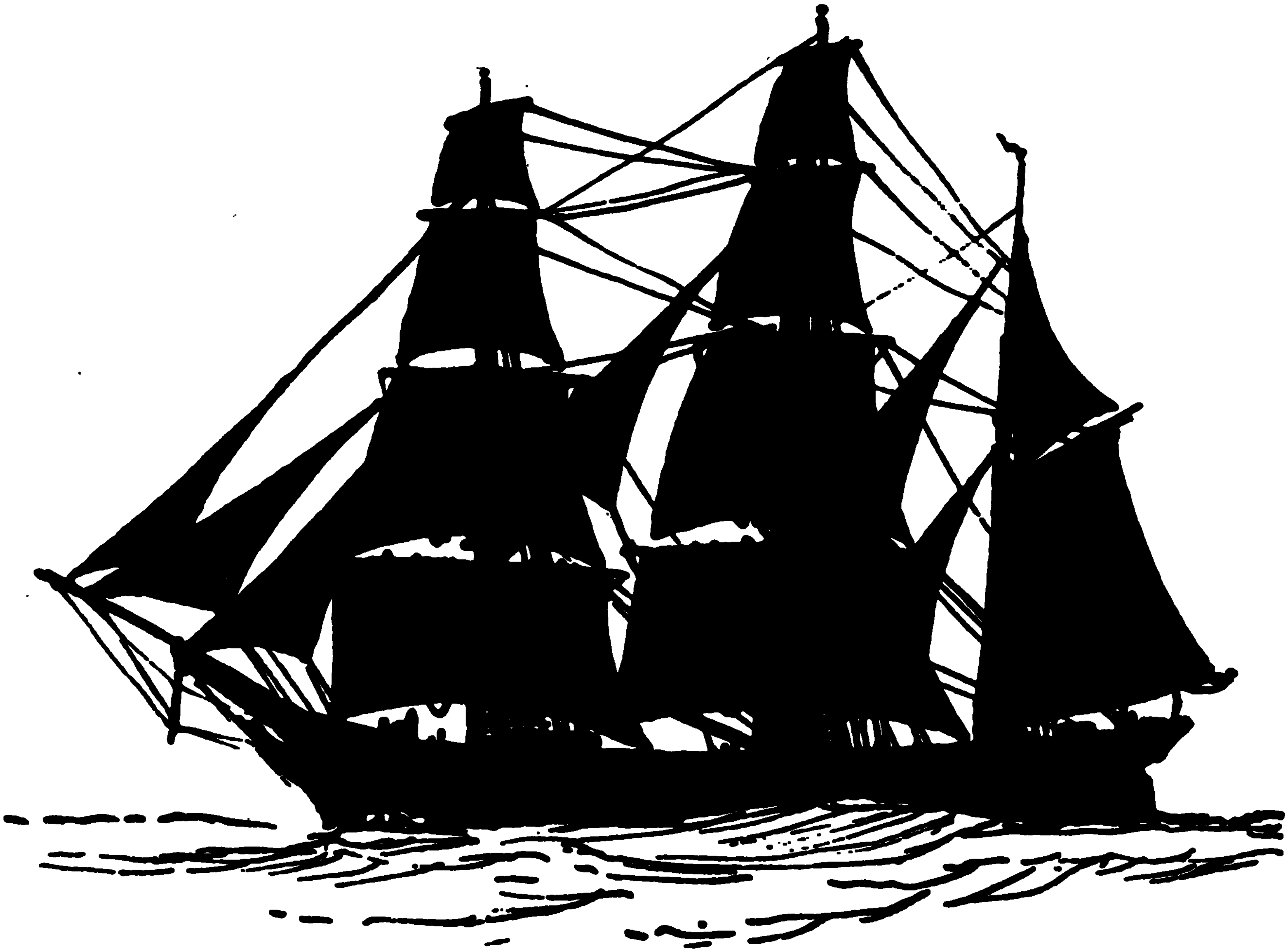
AUXILIARY MACHINERY. All machinery other than that required for main propulsion.

BALE CUBIC. The cubic capacity of a cargo hold measured to the inside of the frames or cargo bottoms.

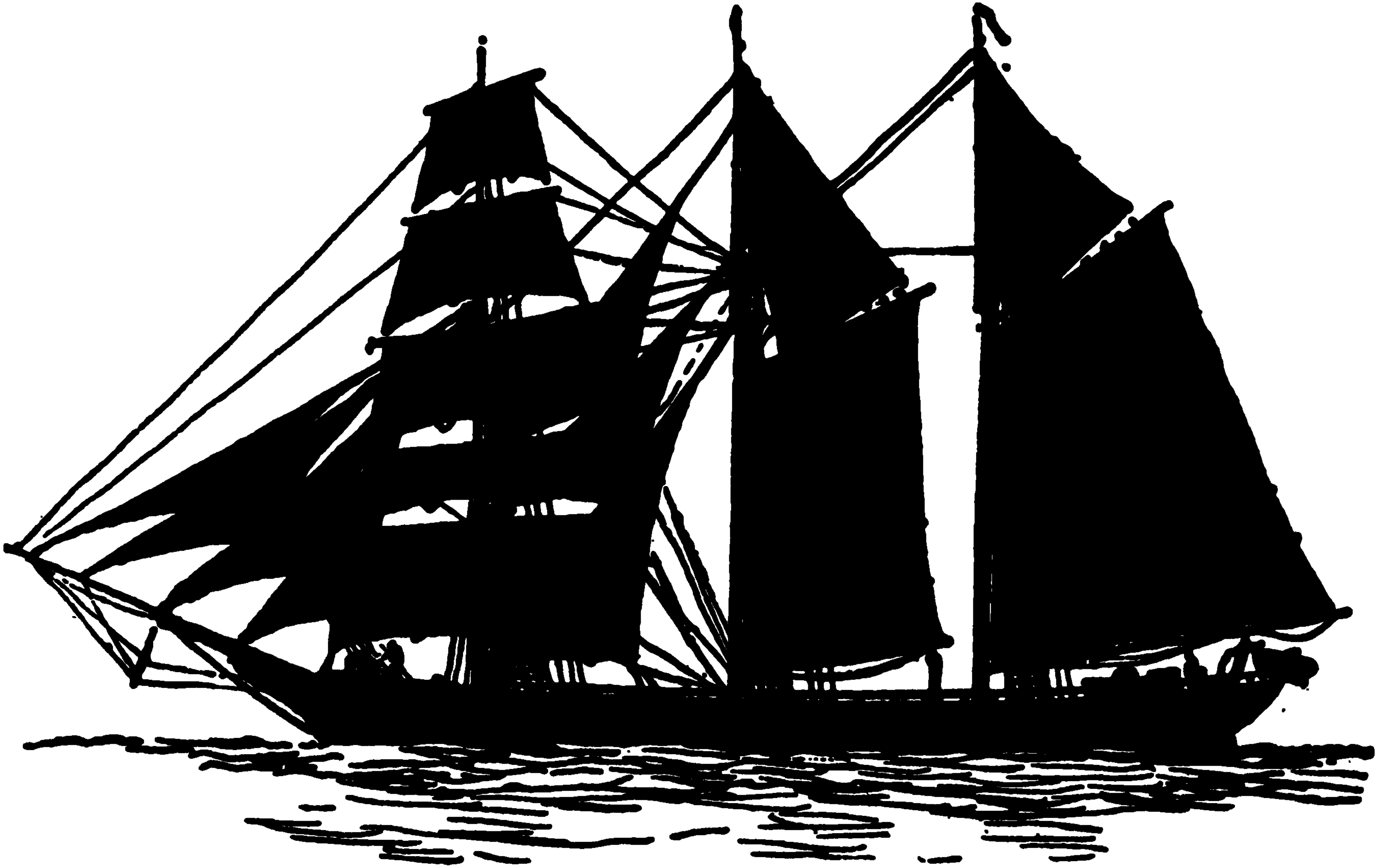
BALLAST. Any solid or liquid weight placed in a ship to increase the draft, to change the trim, or to regulate the stability.

BARGE. A craft of full body and heavy construction designed for the carriage of cargo but having no means for self-propulsion.

BARK. A vessel having three masts, fore, main, and mizzen. The two forward are square rigged and the after, or mizzen, is fore-and-aft rigged.



Bark



Barkentine

BARKENTINE. A vessel having three masts, fore, main, and mizzen. The foremast is square rigged and the main and mizzen fore-and-aft rigged.

BASELINE. A fore-and-aft reference line at the upper surface of the flat plate keel at the centerline for flush steel plated vessels, or at the lowest point of the keel timber on a wooden vessel.

BEAK. Originally, a beam shod or armed with a metal head or point projecting from the bow of an ancient galley. Later, any structure, usually ornamental, fitted at the stem above the waterline at deck level.

BEAM. The extreme width of a ship.

BEAM, DECK. An athwartship horizontal structure member, supporting a deck or flat.

BEAM KNEE. See KNEE, BEAM.

BEAM, MOLDED. The maximum breadth of the hull measured between the inboard surfaces of the side shell plating of flush-plated ships, or between the outboard surfaces of the planking on wooden vessels.

BERTH. Where a ship is docked or tied up; a place to sleep aboard; a bunk or bed.

BILGE. Intersection of bottom and side. May be rounded or angular as in a chine-form hull. The lower parts of holds, tanks and machinery spaces where bilge water may accumulate.

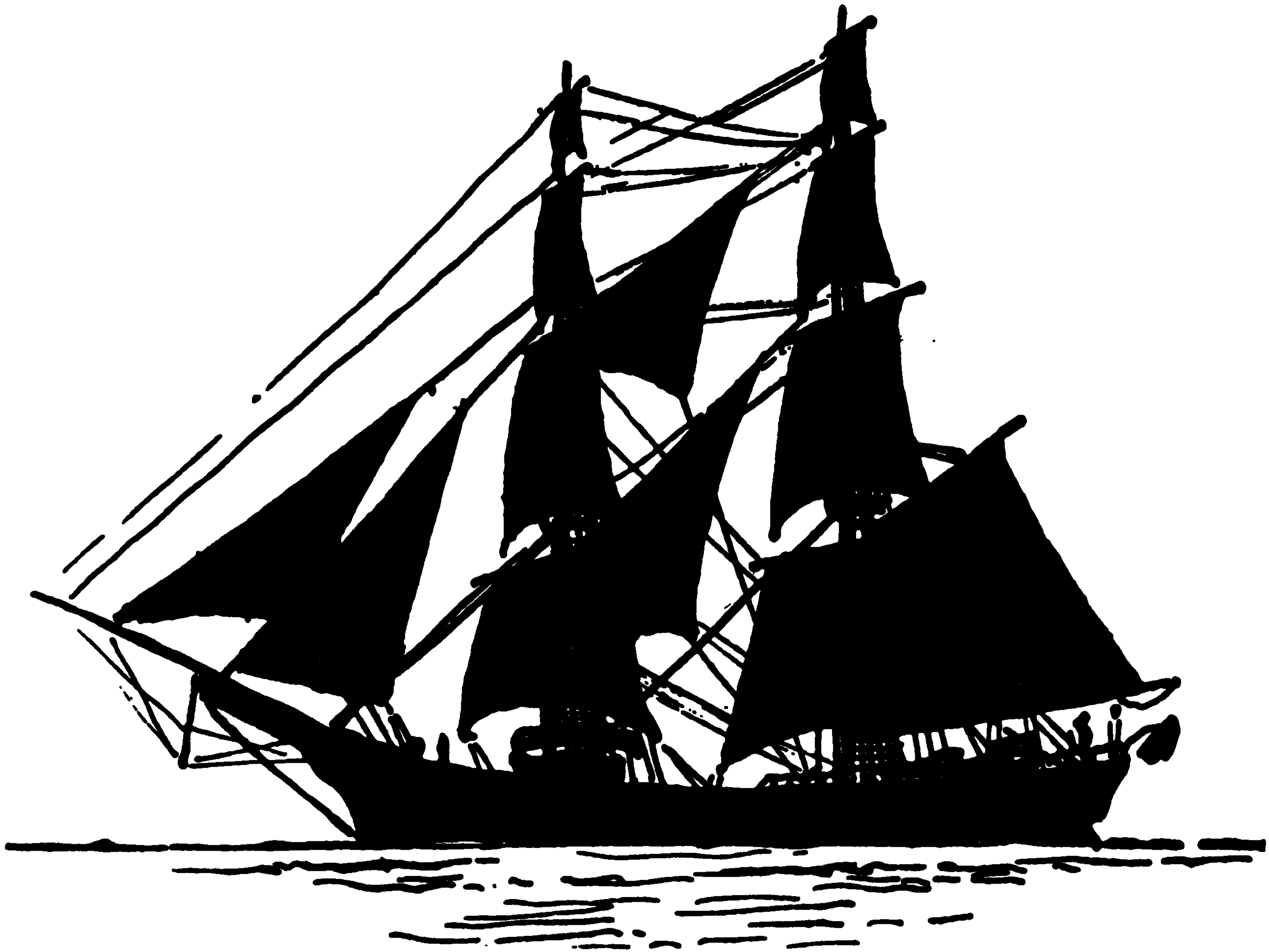
BILGE KEEL. A long longitudinal fin fitted at the turn of the bilge to reduce rolling. Commonly it consists of plating attached to the shell plating by welding or by angles.

BLANKETING. Reducing the effect of wind on a sail by placing another sail or structure upwind.

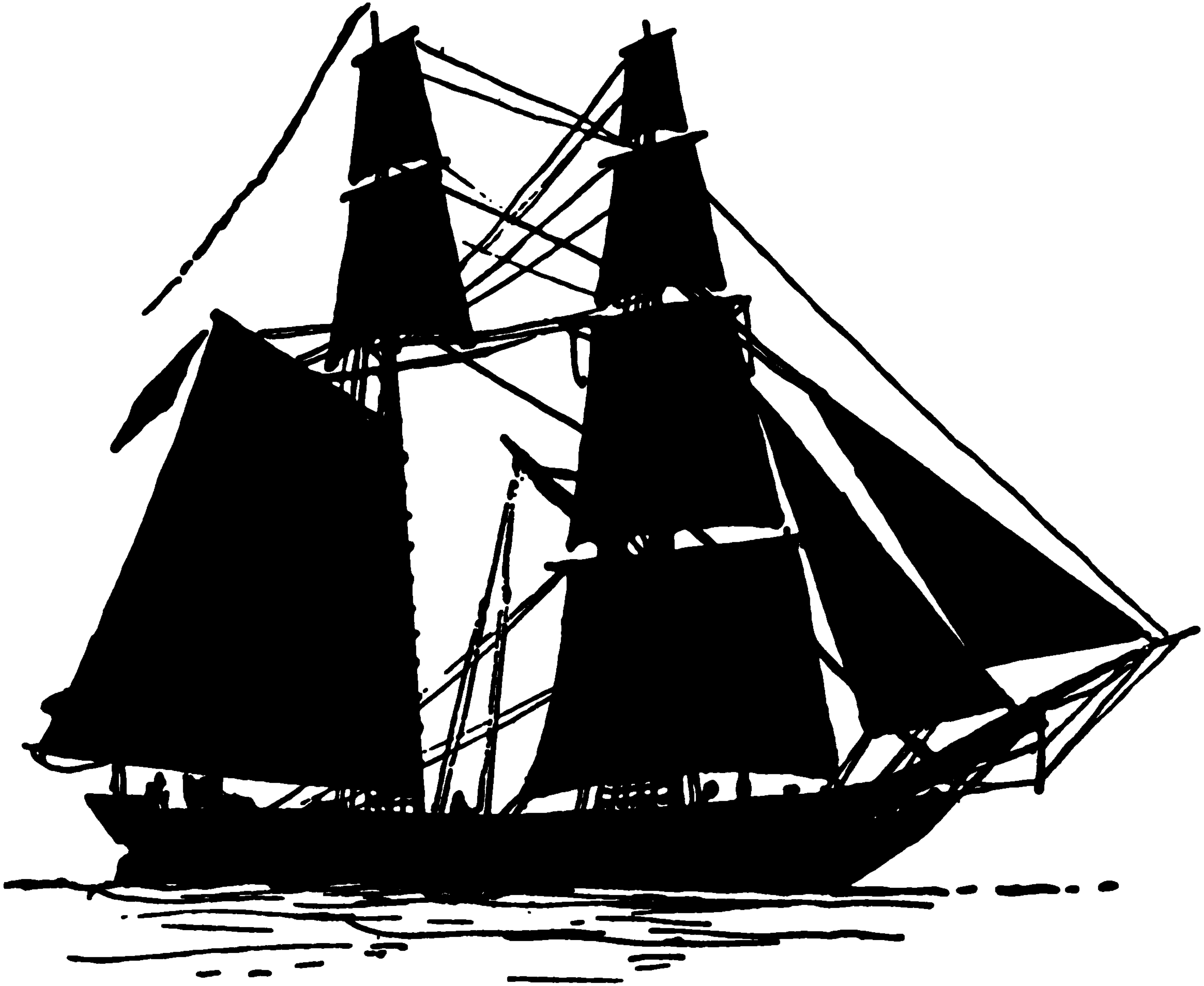
BOILER. Any vessel, container, or receptacle capable of generating steam by the internal or external application of heat.

BOILER, FIRETUBE. A boiler in which the hot gases from the furnace are led to the uptake through tubes around which the water circulates and is converted into steam.

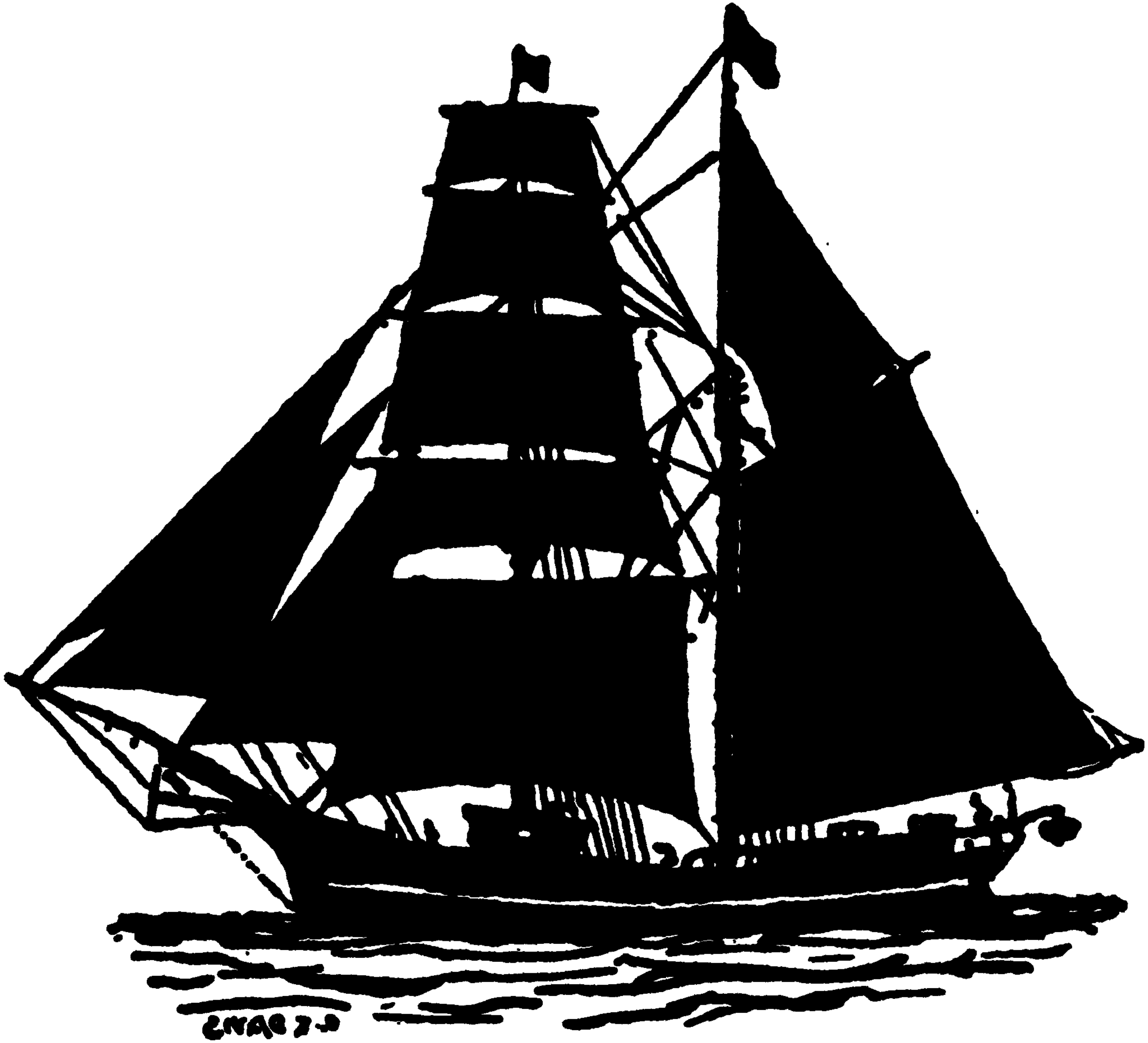
BOILER, SCOTCH. A firetube boiler consisting of a cylindrical shell with internal circular corrugated furnaces in the lower part. The hot gases pass to a combustion chamber in the back of the boiler, and from there return through tubes to the front end and uptake. The water occupies all of the space within the cylindrical shell not taken up by the furnaces and the tubes.



Brig



BRIGANTINE



HERMAPHRODITE BRIG

BOILER, WATERTUBE. A boiler in which the flames and hot gases act on the outside of the tubes through which the water circulates. The feedwater generally enters a top drum and flows down to a lower one. It then returns through tubes about which the hot gases pass to the upper drum where the steam separates.

BOOBY HATCH. An access hatch in a weather deck, protected by a hood from sea and weather. Also called COMPANIONWAY.

BOOM. A spar used in handling cargo or supporting the upper or lower edge of a fore-and-aft sail. One end is usually hinged to a mast.

BOOMING. The act of swinging the unhinged end of a boom to relocate cargo or reposition a sail.

BOW. The forward end of a ship.

BOW LINE. The intersection of the molded hull surface forward of amidships with a vertical longitudinal plane not on the centerline. See also BUTTOCK.

BOWSPRIT. A spar projecting forward over the bow for the purpose of holding the lower ends of the head sails and providing support for the forestays.

BRAKE HORSEPOWER. See HORSEPOWER.

BREADTH, MOLDED. See BEAM, MOLDED.

BREAKWATER. Inclined bulwark-like structure on a weather deck to deflect overboard water coming over the bow or over the gunwale and moving aft.

BRIDGEHOUSE. The structure that houses the navigating bridge.

BRIDGE, NAVIGATING. The conning station or command post of a ship.

BRIG. A two-masted sailing ship, square-rigged on both masts. Also a ship's jail.

BRIGANTINE. A two-masted sailing ship, square-rigged on the forward mast, fore-and-aft rigged on the lower mainmast and with a square topsail on the upper mainmast.

BUILDING BASIN. A structure essentially similar to a graving dock, in which one or more ships or parts of ships may be built at one time; no launching operation is required, the ship being floated by flooding the basin.

BUCKETS. A term frequently applied to the blades on a paddle wheel.

BULK CARGO. Cargo made up of commodities such as oil, coal, ore, grain, etc., and not shipped in bags or containers.

BULKHEAD. The vertical partition walls which subdivide the interior of a ship into compartments or rooms. Bulkheads are distinguished by their location, use, kind of material or method of fabrication, such as forepeak, longitudinal, transverse, watertight, wire mesh, pilaster, etc. Bulkheads which contribute to the strength of a vessel are called strength bulkheads. Those which are essential to the watertight subdivision are watertight or oiltight bulkheads; gastight bulkheads serve to prevent the passage of gas or fumes.

BULKHEAD, AFTERPEAK. A term applied to the first main transverse bulkhead forward of the sternpost. This bulkhead forms the forward boundary of the afterpeak tank.

BULKHEAD, COLLISION OR FOREPEAK. The foremost main transverse watertight bulkhead. It extends from the bottom of the hold to the freeboard deck and it is designed to keep water out of the forward hold in case of bow collision damage.

BULKHEAD DECK. The uppermost deck up to which the transverse watertight bulkheads and shell are carried.

BULWARK. Fore-and-aft vertical plating or planking immediately above the upper edge of the sheer strake encompassing the upper deck edge.

BUNKER. Stowage spaces for eighter oil or coal fuel. BUNKERING is the act of fueling a ship.

BUOYANCY. The tendency of a body to float when immersed in water. The center of buoyancy is the point in a ship where the sum of all upward forces is assumed to act.

BUTTOCK. The intersection of the molded surface abaft amidships with any vertical longitudinal plane not on the centerline. See BOW LINE.

CAMBER. The rise or crown of a deck, athwartship; also called round of beam.

CAPSTAN. A warping head with a vertical axis used for handling mooring and other lines. It may have at its base a wildcat for handling anchor chain.

CARGO BOOM. See BOOM.

CARGO PORT. Opening in a ship's side for loading and unloading cargo.

CENTER GIRDER. A vertical plate on the ship's centerline between the flat keel and inner bottom or rider plate, extending the length of the ship. Also called center vertical keel (CVK) or center keelson.

CENTERLINE. The middle line of the ship, extending from stem to stern at any level.

CLEAT. A fitting having two arms or horns around which ropes may be made fast.

CLOSE HAULED. Sailing with the wind at a small angle off the bow--requires hauling in the sails to a point where they are close to a fore-and-aft orientation.

COAMING, HATCH. The vertical plating or planking bounding a hatch for the purpose of stiffening the edges of the opening and resisting entry of water below.

COFFERDAM. Narrow void space between two bulkheads or floors that prevents leakage between the adjoining compartments.

COLLIER. A ship which carries coal as its cargo.

COLLISION BULKHEAD. See BULKHEAD, COLLISION.

COMPANIONWAY. An access hatchway in a deck, with a ladder leading below, generally for the crew's use.

COMPARTMENTATION. The subdividing of the hull by transverse watertight bulkheads so that the ship may remain afloat under certain assumed conditions of flooding.

CONTROLLABLE-PITCH PROPELLER. A screw propeller where the blades can be rotated on their own axes so as to change their angle of attack to the water, i.e., their pitch. This permits changing speed through the water without changing RPM. When the blades can be rotated to a negative angle of attack so as to deliver reverse thrust, it is called a CONTROLLABLE-REVERSIBLE-PITCH (or CRP) propeller. A common misnomer is VARIABLE PITCH; this applies to a fixed pitch propeller where the pitch of the blade sections is varied radially to obtain a better load distribution on the propeller.

COUNTER. See FANTAIL.

CUTTER. A fore-and-aft rigged sailing boat with jib, forestaysail, and mainsail with the mast stepped farther aft than on a sloop.

CUTWATER. The forepart of a ship's stem.

DAMAGED STABILITY. The ability of a damaged vessel to resume an upright position when heeled.

DAVIT. A crane arm for handling lifeboats, anchors, stores, etc.

DEADRISE. Athwartship rise of the bottom from the keel to the bilge.

DEADWEIGHT. The carrying capacity of a ship at any draft and water density. Includes weight of cargo, fuel, lubricating oil, fresh water in tanks, stores, passengers and baggage, crew and their effects.

DECK. A platform in a ship corresponding to a floor in a building. It is the plating, planking, or covering of any tier of beams either in the hull or superstructure of a ship.

DECKBEAM. See BEAM, DECK.

DECK, BULKHEAD. See BULKHEAD DECK.

DECK, FREEBOARD. See FREEBOARD DECK.

DECK MACHINERY. Steering gear, capstans, windlasses, winches, and miscellaneous machinery located on the decks of a ship.

DECK, TONNAGE. See TONNAGE DECK.

DECK, WEATHER. See WEATHER DECK.

DEPTH, MOLDED. The vertical distance from the molded baseline to the top of the freeboard deck beam at side, measured at midlength of the ship.

DISPLACEMENT, LIGHT. The weight of the ship complete including hull, machinery, outfit, equipment, and liquids in machinery but excluding all items of the deadweight.

DISPLACEMENT, LOADED. The displacement of a ship when floating at her greatest allowable draft. It is equal to the weight of water displaced and is the sum of the light displacement and the deadweight. See also TONNAGE.

DOUBLE BOTTOM. Compartments at the bottom of a ship between inner bottom and the shell plating, used for ballast water, fresh water, fuel oil, etc.; Sometimes used as a substitute for the term INNER BOTTOM.

DRAFT. The depth of the ship below the waterline measured vertically to the lowest part of the hull, propellers, or other reference point. When measured to the lowest projecting portion of the vessel, it is called EXTREME DRAFT; when measured at the bow, it is called FORWARD DRAFT: and when measured at the stern, the AFTER DRAFT. The average of the forward draft and the after draft is the MEAN DRAFT: the mean draft when in full load condition is the LOAD DRAFT. Also, in cargo handling, the unit of cargo being hoisted on or off the ship by the cargo gear in one particular hoist.

DRAFT MARKS. The numbers on each side of a ship at the bow and stern, and sometimes amidships, to indicate the distance from the lower edge of the number to the bottom of the keel or other fixed reference point. The numbers are 6 inches high and spaced 12 inches bottom to bottom vertically.

DRAG. The designed excess of draft aft over that forward when fore and aft drafts are measured from the designed waterline.

DUNNAGE. Loose wood or waste material placed in a cargo hold to prevent the cargo from shifting and to protect it from dampness.

DYNAMOMETER. A gauge for the measurement of a force.

EFFECTIVE HORSEPOWER. See HORSEPOWER.

ENTRANCE. That portion of a ship's body forward of the parallel middle-body or the point at which the slope of the sectional area curve is zero.

EVEN KEEL. A ship is said to be on an even keel when the keel is horizontal.

FAIR. To smooth or fair up a ship's lines; eliminating irregularities; to assemble the parts of a ship so that they will be fair, i.e., without kinks, bumps, or waves; to bring rivet holes in alignment.

FAIRLEAD OR FAIRLEADER. A fitting or device used to preserve or to change the direction of a rope so that it will be delivered on a straight lead to a sheave or drum.

FALL. The rope used with blocks to make up a tackle. The end secured to the block is called standing part; the opposite end, the hauling part.

FANTAIL. The overhanging stern section of ships with round or elliptical after endings to uppermost decks and which extend well abaft the after perpendicular. Also called counter.

FATHOM. A measure of length, equivalent to 6 linear feet, used for depths of water and lengths of anchor chain.

FATHOMETER. A device to measure the depth of water, by timing the travel of a sound wave from the ship to the ocean bottom and return.

FEATHERING. Originally applied to oars being turned so that their blades were parallel to the line of motion on a return stroke, this term adapted to the rotation of paddle-wheel blades on their own axes so that they would emerge from the water vertically at the end of their power stroke thus reducing the carry-over of water and consequent churning.

FLANKING. Usually applied to steering a towboat when the propeller or paddle wheel is reversed. Flanking rudders are installed forward of the propulsion device so as to utilize the race of the reversed propeller to develop additional maneuvering side forces.

FLAT FLOORED. Without deadrise.

FLOODABLE LENGTH. The length of ship which may be flooded without sinking below her safety or margin line. The floodable length of a vessel varies from point to point throughout her length and is usually greatest amidship and least near the quarter length.

FLOOR. Verticle transverse plate or planking immediately above the bottom shell, often located at every frame, extending from bilge to bilge.

FLUSH-DECK SHIP. A ship constructed with an upper deck extending throughout her entire length without a break or a superstructure such as forecastle, bridge, or poop.

FORE. A term used in indicating portions or that part of a ship at or adjacent to the bow. Also applied to that portion and parts of the ship lying between amidships and the stem; as, forebody, forehold, and foremast.

FORE-AND-AFT. In line with the length of the ship; longitudinal.

FORE-AND-AFT RIGGED. A sailing vessel arranged so that its principal sails, in the at-rest condition, lie in the vertical, fore-and-aft centerline plane of the ship. The standing rigging supporting the masts is so arranged that the sails can swing to port or to starboard without interference to capture the wind required for propulsion.

FORE-AND-AFT SAIL. A sail whose at-rest position in dead air is in line with the fore-and-aft centerplane of the vessel.

FOREBODY. That portion of the ship's body forward of amidships.

FORECASTLE. A raised forward deck; also a forward living compartment for the crew. Often written and pronounced "fo'c'sle." Originally a turreted structure affording vantage for a ship's fighting men.

FOREFOOT. The lower end of a ship's stem which curves to meet the keel.

FOREPEAK. The watertight compartment at the extreme forward end. The forward trimming tank.

FORWARD. In the direction of the stem.

FORWARD OR FORE PERPENDICULAR. See LENGTH BETWEEN PERPENDICULARS.

FRAME. A term used to designate one of the transverse members that make up the riblike part of the skeleton of a ship. The frames act as stiffeners, holding the outside planking or plating in shape and maintaining the transverse form of the ship.

FREEBOARD. The distance from the waterline to the upper surface of the freeboard deck at side.

FREEBOARD DECK. Deck to which freeboard is measured; the uppermost continuous deck having permanent means of closing all weather openings.

FULL-RIGGED SHIP. A sailing ship of three or more masts rigged with square sails on all masts.

FUNNEL. The smokestack of a steam or motor vessel.

F. W. An abbreviation for fresh water, either that in which a vessel is floating or what which is carried aboard for ballast, cooling, or consumption. It is generally assumed to have a specific gravity of 1, a density of 62.4 pounds per cubic foot, and a volume of 36 cubit feet per long ton.

GAFF. A boom, hinged or yoked to the afterside of a mast, from which a sail is suspended.

GALLEY. A cookroom or kitchen on a ship.

GANTRY CRANE. A hoisting device, usually travelling on rails, having the lifting hook suspended from a car which is movable horizontally in a direction transverse to the rails.

GIRDER. A continuous member running fore-and-aft under a deck for the purpose of supporting the deck beams and deck.

GRAIN CUBIC. The cubic capacity of a cargo hold measured to the shell plating rather than to the inside of the frames or cargo battens.

GRAVING DOCK. A basin excavated at a waterway and connected thereto by gates or a caisson which may be opened to let a vessel in or out and the water pumped out. Initially designed for repairing the underwater bodies of ships, graving docks are now frequently used as building basins for large ships.

GROSS TONNAGE. See TONNAGE.

GROUND TACKLE. A general term for anchors, cables, wire ropes, etc., used in anchoring a ship to the bottom.

GUNDALOW. A long narrow boat usually poled or paddled; a variation of gondola.

GUNWALE. The heavy plating or planking where the weather deck stringer meets the side of a ship, the term deriving from the area of supported deck where guns were carried.

HALYARD. Light line used in hoisting signals, flags, etc.

HATCH (HATCHWAY). An opening in a deck through which cargo and stores are loaded or unloaded.

HAWSEPIPE. Tube through which anchor chain is led overboard from the windlass wildcat on deck through the ship's side. Bolsters form rounded endings at the deck and shell to avoid sharp edges. Stockless anchors are usually stowed in the hawsepipe.

HEAD. Toilet; believed to be derived from "Ship's head," when a small platform outside the bulwarks near the bow was the only semblance of sanitary facilities.

HEADLOG. In river craft of rectangular shape, the member at the extreme end between the rake shell plating and the deck. Usually a vertical plate of considerable thickness owing to its susceptibility to damage in service.

HEEL. The inclination of a ship to one side. See also LIST. Also the corner of an angle, bulb angle or channel, commonly used in reference to the molded line.

HOGGING. Straining of the ship that tends to make the bow and stern lower than the middle portion. See also SAGGING.

HOLD. The large space below deck for the stowage of cargo; the lowermost cargo compartment.

HORSEPOWER. A unit of power equal to 550 foot-pounds per second. The power designator (IHP) means indicated horsepower and is customarily used for the horsepower of steam reciprocating engines. The indicator instrument produces a pattern of steam pressure versus stroke for a single cycle of each cylinder. From the area under the resulting curves, the power of each cylinder can be calculated and summed to get the total IHP. Diesel engine power can also be measured with an indicator instrument, but it is customary to attach a waterbrake to the output shaft of the engine which gives a value of brake horsepower (or BHP) output. With steam turbine and gear systems the power is usually measured with a torsionmeter on the lineshaft or tailshaft between the gear and the propeller. This gives the shaft horsepower (or SHP). Effective horsepower (EHP) is obtained from the product of the speed of a ship and the resistance to its motion through the water at that speed.

HULL. The structural body of a ship, including shell plating or planking, framing, decks, bulkheads, etc.

HULL GIRDER. That part of the hull structural material effective in the longitudinal strength of the ship as a whole, which may be treated as analagous to a girder.

INBOARD. Inside the ship; toward the centerline.

INDICATED HORSEPOWER. See HORSEPOWER.

INNER BOTTOM. Plating forming the top of the double bottom; also called tank top.

KEEL. The principal fore-and-aft component of a ship's framing, located along the centerline of the bottom and connected to the stem and stern frames. Floors or bottom transverses are attached to the keel.

KETCH. A two-masted, fore-and-aft rigged boat similar to a yawl but with a larger mizzen and having the mizzenmast stepped forward of the rudder post.

KING POST. A strong vertical post used instead of a mast to support a boom and rigging to form a derrick; also called samson post.

KNEE, BEAM. Bracket connecting a deck beam and frame.

KNOT. See SPEED.

KNUCKLE. An abrupt change in direction of the plating, frames, keel, deck, or other structure of a ship.

KORT NOZZLE. A cylindrical nozzle of hydrofoil-shaped cross section that surrounds a screw propeller to accelerate the flow and to augment thrust at low speeds.

LASH. An acronym for LIGHTER aboard ship.

LATEEN RIG. A mast and yard system for supporting a fore-and-aft triangular sail. The rig comprises a short mast that supports an inclined supple yard from which the sail is suspended. The yard nearly touches the deck forward of the mast and rises to approximately twice the mast height abaft the mast. The sail is loose-footed and is controlled by a sheet at the after apex at deck level. Multiple lateen rigs are sometimes used.

LENGTH, OVERALL. The extreme length of a ship measured from the foremost point of the stem to the aftermost part of the stern.

LENGTH BETWEEN PERPENDICULARS. The length of a ship between the forward and after perpendiculars. The forward perpendicular is a vertical line at the intersection of the fore side of the stem and the summer load waterline. The after perpendicular is a vertical line at the intersection of the summer load line and the after side of the rudder post or sternpost, or the centerline of the rudder stock if there is no rudder post or sternpost.

LIFEBOAT. A boat carried by a ship for use in emergency.

LIGHTER. A barge used to move goods in a harbor or to load and unload ships not secured to a pier.

LIGHTSHIP WEIGHT. See TONNAGE. See also DISPLACEMENT, LIGHT.

LINES (PLAN). The plans that show the shape or form of the ship. From the lines drawn full size on the mold-loft floor, templates are made for the various parts of the hull.

LINE SHAFTING. Sections of main propulsion shafting between the machinery and the tail shaft.

LIST. The leaning or inclination of a ship to one side. If the centerline plane of a ship is not vertical, as when there is more weight on one side than on the other, she is said to list, or to heel.

LOAD WATERLINE. The line on the LINES PLAN of a ship, representing the intersection of the ship's form with the plane of water surface when the ship is floating at the summer freeboard draft or at the designed draft.

LONGITUDINALS. Fore-and-aft structural shape, plate, or timber members attached to the underside of decks, flats, or to the inner bottoms, or on the inboard side of the shell.

LONG TON. A ton of 2,240 pounds.

LOOSE FOOTED. A sail with its lower edge, or foot, not attached to a boom.

LWL. An acronym for load waterline.

MAST. A tall vertical or raked structure, usually of circular section, located on the centerline of a ship and used to carry sails, rigging, navigation lights, radio antennae, booms, etc. See also KING POST. Sailing ship masts are usually designated by their fore-and-aft position along the ship's centerline and, vertically, by the sails that they support. The tallest mast is called the mainmast; forward of the mainmast is the foremast; aft of the mainmast is the mizzenmast. In a four-masted ship, the aftermast is called the jiggermast. On ships with more than four masts, they are usually numbered from fore to aft.

When a series of masts are stepped vertically atop each other, the lowest mast is given the designation listed above. On a ship-rigged vessel, the upper masts bear an additional designation, for example, starting from the deck, foremast, fore-topmast, fore-topgallent mast, fore-royal mast, fore-skysail pole. On fore-and-aft rigged vessels there are usually fewer stepped masts but similar designations are used.

METRIC TON. A ton of 2,204 pounds.

MIDSHIP. See AMIDSHIPS.

MIDSHIP SECTION. A drawing showing a typical cross section of the hull and superstructure at or near amidships, and giving the scantlings of the principal structure members.

MOLD LOFT. A building on the floor of which a ship's lines are enscribed to full scale. Wooden or heavy paper templates are then made from these lines to be used in laying out structural members and for forming shell plates, deck plates, bulkheads, and brackets.

MOORING. Securing a ship at a pier or elsewhere by lines or cables so as to limit her movement.

MOORING CHOCK. A deck mounted, flaired opening through which the ship's lines are handled when tying up to a pier or quay.

OBO. An acronym for a vessel designed to carry oil, bulk cargoes or ore cargoes.

ONE COMPARTMENT SUBDIVISION. A standard of subdivision of a ship by bulkheads, which will result in the ship remaining afloat with any one compartment flooded, under specified conditions as to permeability of the compartment and the draft of the ship before flooding of the compartment.

OUTBOARD. Abreast or away from the centerline towards the side; outside the hull.

OVERHANG. The portion of a ship's bow or stern clear of the water which projects beyond the forward and after perpendiculars.

PARALLEL MIDDLEBODY. The amidship portion of a ship within which the contour of the underwater hull form is unchanged.

PEAK. See AFTERPEAK, FOREPEAK.

PITSAW. A long hand saw with a handle at each end used for cutting a log lengthwise into planks. It is worked by two men, one standing above the log and the other standing in a pit below the log.

POOP DECK. A partial weather deck above the main deck in the after part of a ship.

PORT, CARGO. An opening in the side plating provided with a watertight cover or door and used for loading and unloading.

PORT SIDE. The left-hand side of a ship when looking forward. Opposite to starboard.

POWER PLANT. On board ship the main power plant comprises all machinery used principally to drive the main propulsion device. The auxiliary power plant is the machinery used to provide power for all other shipboard functions.

PROPELLER. A revolving screw-like device that drives the ship through the water, consisting of two or more blades; sometimes called a screw or wheel.

PROPULSIVE COEFFICIENT. The overall efficiency of the propulsion system; the effective horsepower divided by the shaft horsepower or EHP/SHP.

QUARTERDECK. The afterpart of a ship's upper deck, forward of, but sometimes including the poop deck, formerly reserved for officers and cabin passengers.

RAFT. A flat structure for support or conveyance of cargo or people on a body of water.

RAKE. A term applied to the fore-and-aft inclination from the vertical, of the mast, smokestack, stem, etc. In barges, the end portion of the hull, in which the bottom rises from the parallel middlebody to meet the deck at the headlog.

REEFER. Colloquialism for refrigerator or refrigerated.

RIG. The configuration of ropes, sails, and spars of a sailing vessel that characterize the vessel type.

RIGGING. Chains, ropes, fiber lines, and associated fittings and accessories used to support or control masts, sails, spars, and booms.

RISE OF FLOOR. See DEADRISE.

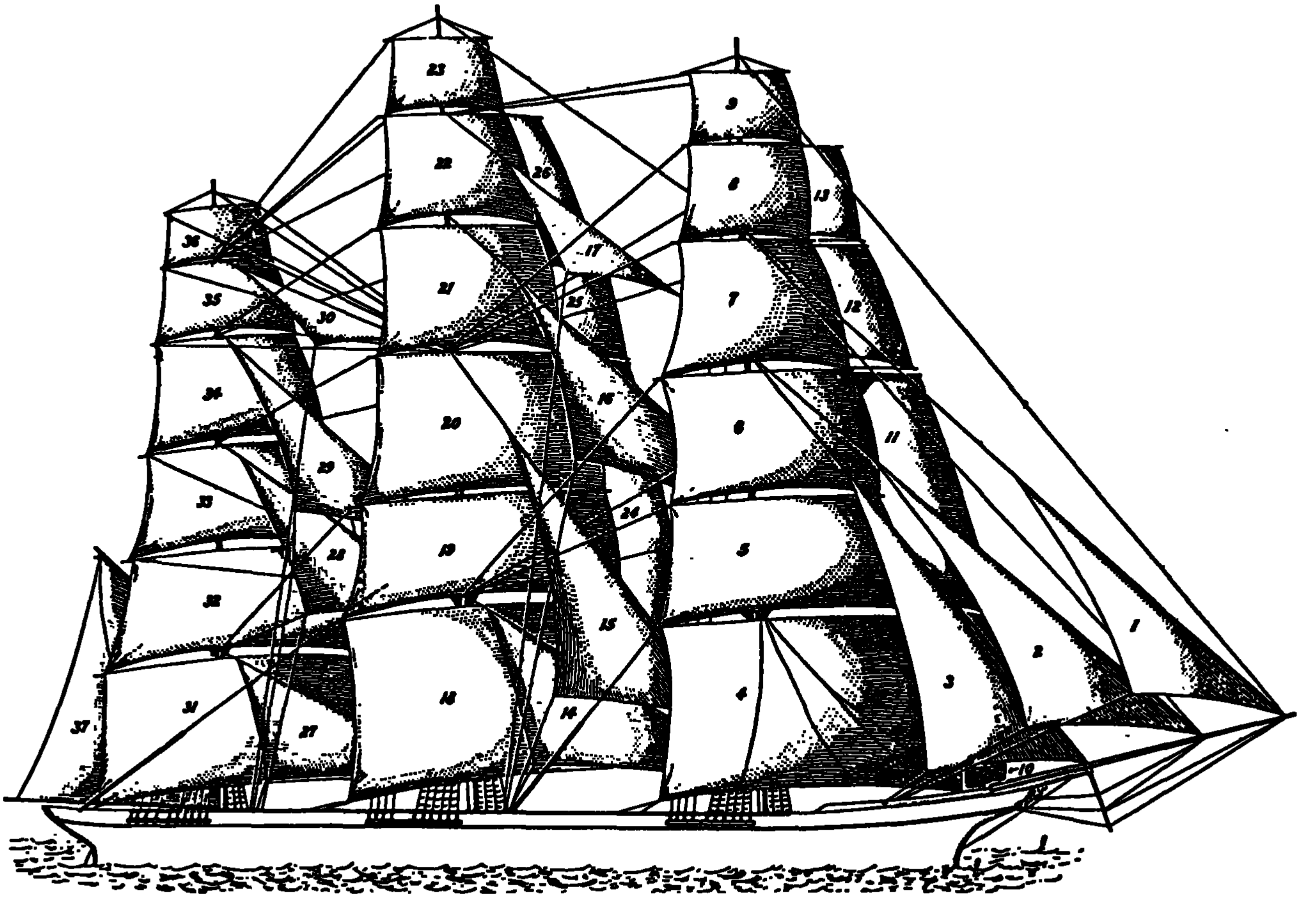
RO/RO. Abbreviation for a vessel designed to carry vehicles, so arranged that the vehicles may be loaded and unloaded by being rolled on or off on their own and/or auxiliary wheels, via ramps fitted to the sides, bow, or stern of the vessel.

RUDDER. A device used to steer a ship. The most common type consists of a vertical hydrofoil rotated by means of a rudder stock that extends down through the counter.

RUDDER STOCK. A vertical shaft that connects the rudder to the steering engine.

RUN. That part of a ship's body aft of the parallel middlebody or the point at which the slope of the sectional area curve is zero.

RUNNING RIGGING. The movable part of a ship's rigging used to control the position or configuration of sails, yards, or booms. On the square sail components of a ship-rigged vessel, this includes the lifts for raising and lowering the yards, the braces for swinging or trimming the yards, and the sheets for trimming the sails; on the fore-and-aft sail components, it includes the topping lifts

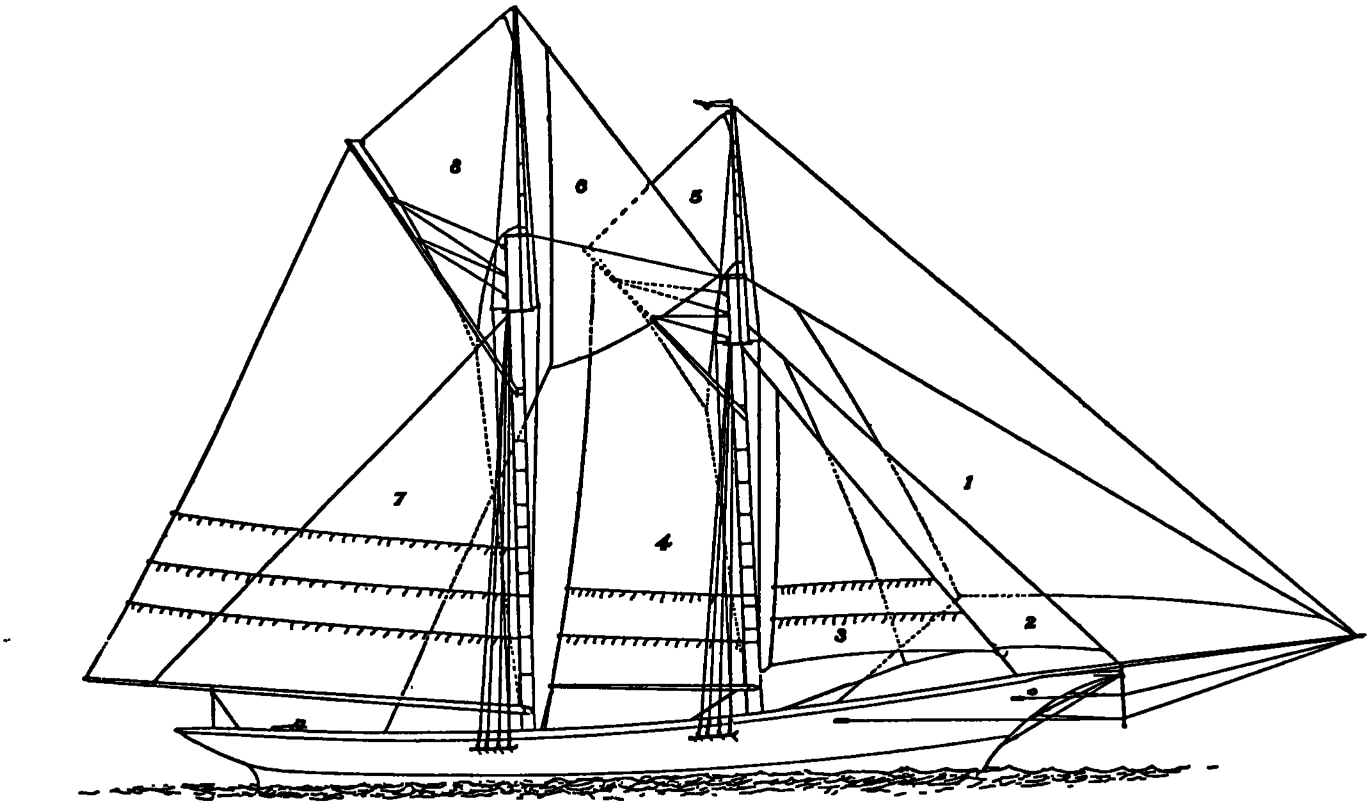


FULL-RIGGED SHIP UNDER ALL PLAIN SAIL to skysails, with all staysails and all port studding sails (sometimes an inner jib and outer jib are fitted instead of one jib, and also an upper and lower main-topmast staysail instead of one staysail, the upper stay leading just below the foretop; double topgallant sails are sometimes fitted) 1 flying jib, 2 jib, 3 fore-topmast staysail, 4 foresail, 5 lower fore-topsail, 6 upper fore-topsail, 7 fore-topgallant sail, 8 fore-royal, 9 fore-skysail, 10 lower studdingsail (never on the main), 11 fore-topmast studding sail, 12 fore-topgallant studding sail, 13 fore-royal studding sail, 14 main staysail, 15 main-topmast staysail, 16 main-topgallant staysail, 17 main-royal staysail, 18 mainsail, 19 lower main topsail, 20 upper main topsail, 21 main-topgallant sail, 22 main royal, 23 main skysail, 24 main-topmast studding sail, 25 main-topgallant studding sail, 26 main-royal studding sail, 27 mizzen stays ail, 28 mizzen-topmast staysail, 29 mizzen-topgallant staysail, 30 mizzen-roya l staysail, 31 mizzen sail (crossjack), 32 lower mizzen topsail, 33 upper mizzen topsail, 34 mizzen-topgallant sail, 35 mizzen royal, 36 mizzen skysail, 37 spanker for the spanker-gaff and the spanker-boom, the trysail and spanker peak halyards and vangs, the spanker and trysail sheets, and the halyards and sheets for the staysails. On a fore-and-aft rig, such as a schooner, the running rigging includes, in addition, the lines for handling the jibs, foresail and mainsail, and the gaff-topsails. For handling cargo booms on a cargo ship, the running rigging includes vangs for swinging the boom from side to side, a topping lift for raising the end of the boom, and the whip used to raise and lower the cargo hook.

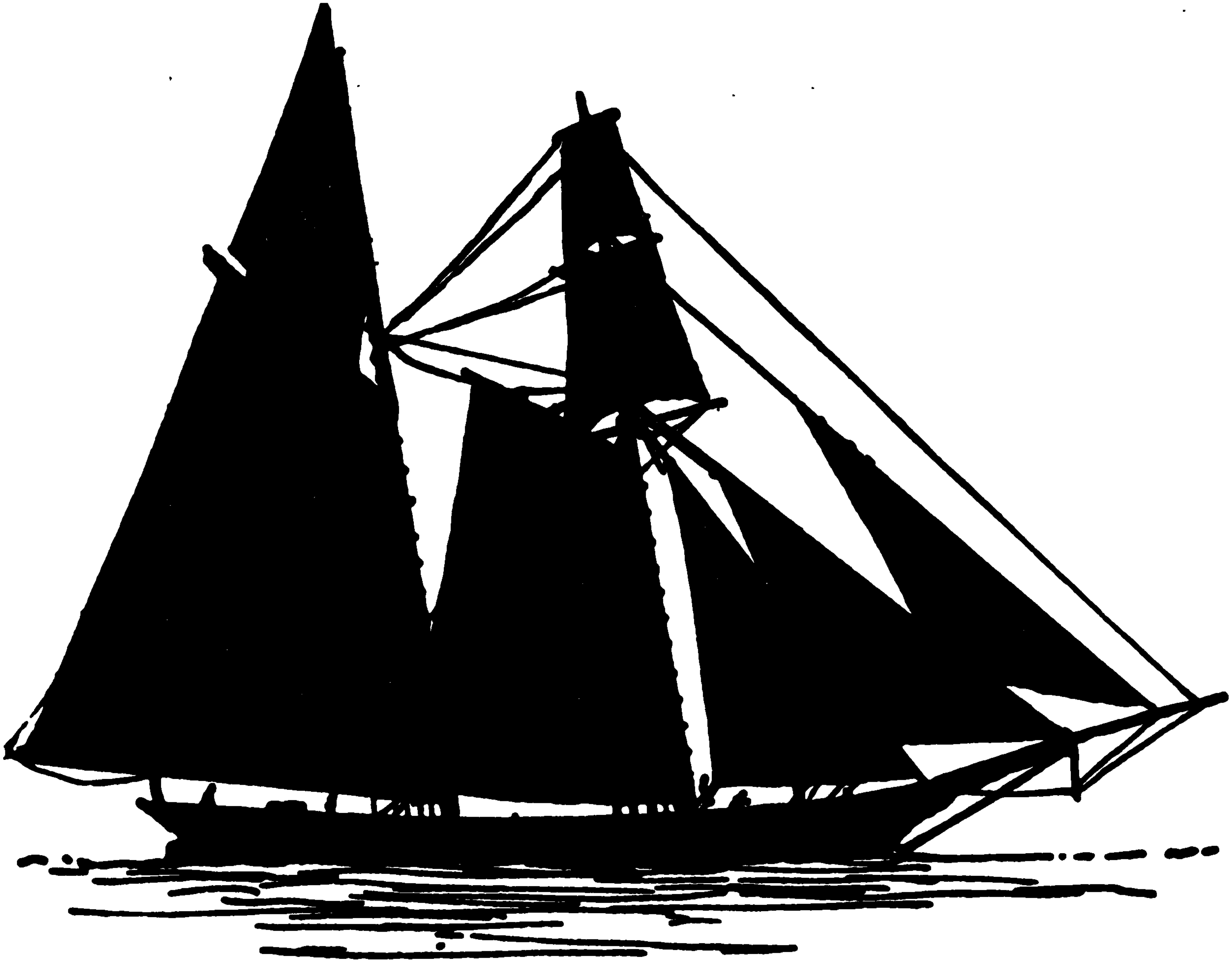
SAGGING. Straining of the ship that tends to make the middle portion lower than the bow and stern. See also HOGGING.

SAILS. A full-rigged ship, although nominally square-rigged, mounts most of the same sails as are found on a fore-and-aft rigged vessel as well. Square sails are basically trapezoidal in shape and their at-rest position is perpendicular to the fore-and-aft centerline of the vessel. Starting from the deck and working upward, the square sails are named for the mast on which they are mounted followed by -course or -sail, topsail, topgallant, sail, royal, skysail, and moonsail or moonraker. These sails are hung from yards by a series of rings at regular intervals but are loose-footed except that the lower corners, or clews, are secured to the yard that supports the sail below. The studding sails may be square, trapezoidal, or triangular; these sails are run outboard, hung from extensions of the yards when the wind is from astern; only the lower studding sail is secured to a swinging boom at its outboard and inboard clews. The fore-and-aft sails on a full-rigged ship include the jibs, staysails, trysails or spencers, and the spanker or driver. The flying jib and the jib are the forwardmost sails; they are triangular sails with the longer side of the triangles hung by rings from jib stays that run from the foremast to the jib boom, which is a forward extension of the bowsprit. The staysails are similar in appearance to the jibs and are hung from the stays that run forward from the top of each mast section. The spanker or driver is the aftermast fore-and-aft sail; it is a trapezoidal sail hung from the spanker gaff and secured at the bottom to the spanker boom, both of which are hinged to the after side of the mizzenmast. The spencers or trysails are similar in that they hang from booms called trysail gaffs hinged to the top of the mainmast and the foremast; however, these are loose-footed sails since there is no room to swing a lower boom across the working part of the deck.

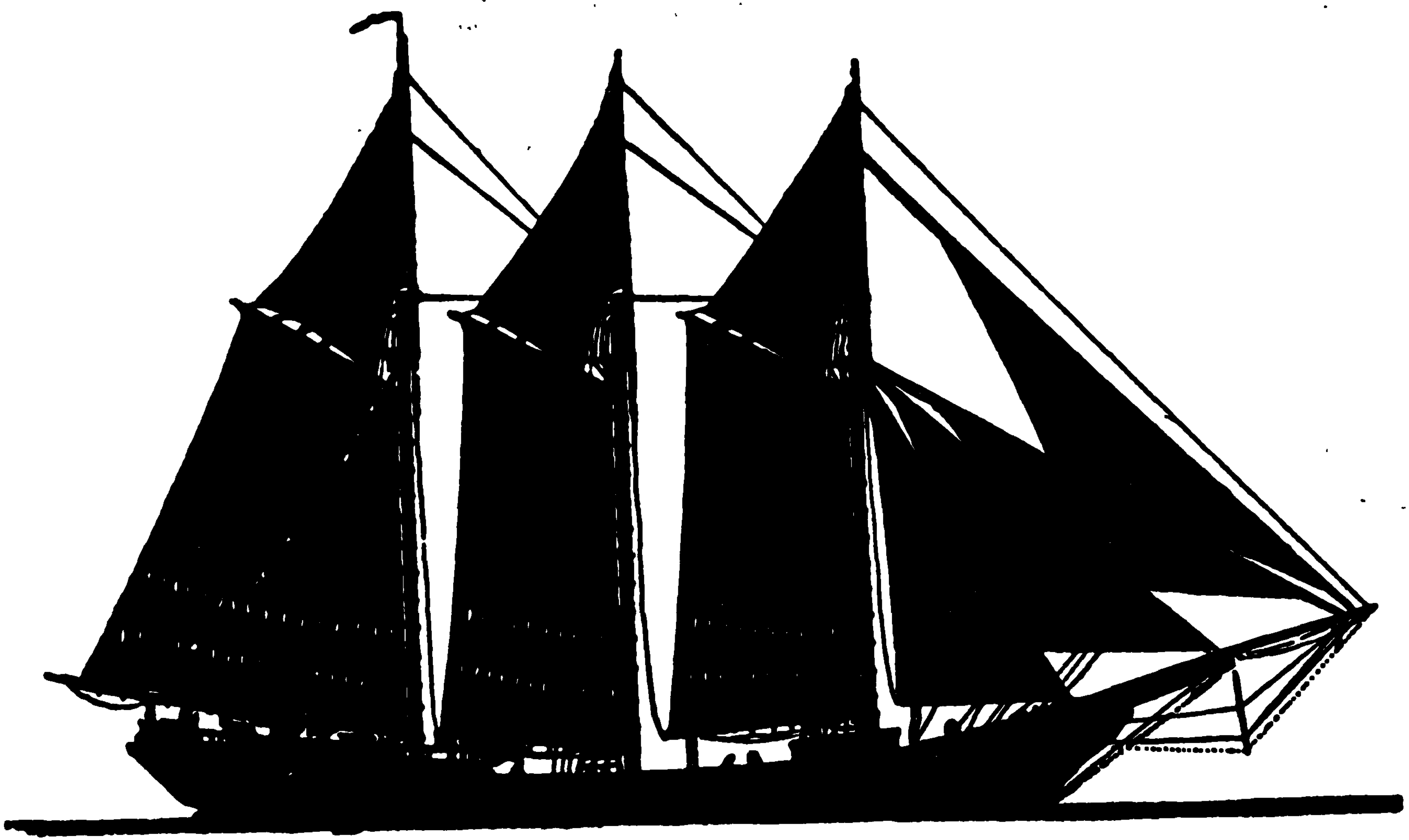
The fore-and-aft sails on a schooner-rigged ship are similar to those on the ship-rig and are similarly designated. Minor exceptions are the jibs that are called inner and outer jibs and the gaff-topsails; the latter are triangular sails that are fitted between the gaff and the mast from which the gaff is hinged. More



SCHOONER'S SAILS
(an inner and an outer jib are sometimes fitted instead of one jib)
1 flying jib, 2 jib, 3 forestaysail, 4 foresail, 5 fore gaff-topsail, 6 main-topmast staysail, 7 mainsail, 8 main gaff-topsail



Topsail Schooner



THREE-MASTED SCHOONER

modern sailing craft often dispense with the gaff and use a triangular sail with its forward side secured to the mast and its lower side secured to a boom.

SCANTLINGS. The dimensions of a ship's frames, girders, plating, etc.

SCANTLING DRAFT. The maximum draft at which a vessel complies with the governing strength requirements. Usually used when the scantling draft is less than the geometrical draft corresponding to the freeboard calculated according to the Load Line Convention.

SCHOONER. A fore-and-aft rigged sailing ship having two masts, with a smaller sail on the foremast, and the mainmast stepped nearly amidships. Typical sails include flying jib, jib, forestaysail, foresail, foregaff-topsail main topmast-staysail, mainsail, and main gaff-topsail. Sometimes square topsails are carried on one or both masts, and schooners have been built with up to seven masts.

SCOW. A large, flat-bottomed non-self-propelled boat with broad square ends.

SCUPPERS. Drains from decks to carry off accumulations of rainwater, condensation or seawater. Scuppers are located in the gutters or waterways, on open decks, and connect to pipes usually leading overboard, and, in corners of enclosed decks to the bilge.

SCUTTLE. A small circular or oval opening fitted in decks to provide access. When used as escape scuttles and fitted with means whereby the covers can be opened quickly to permit exit, they are called quick-acting scuttles. Sometimes used to refer to an air port.

SEABEE. An acronym for a seagoing ship that carries its cargo contained in barges.

SEA CHEST. An enclosure, attached to the inside of the underwater shell and open to the sea, fitted with a portable strainer plate. A sea valve and piping connected to the sea chest passes sea water into the ship for cooling, fire, or sanitary purposes. Compressed air or steam connections may be provided to remove ice or other obstructions.

SHAFT HORSEPOWER. See HORSEPOWER.

SHAFT TUNNEL, SHAFT ALLEY. A watertight enclosure for the propeller shafting large enough to walk in, extending aft from the engine room to provide access and protection to the shafting in way of holds.

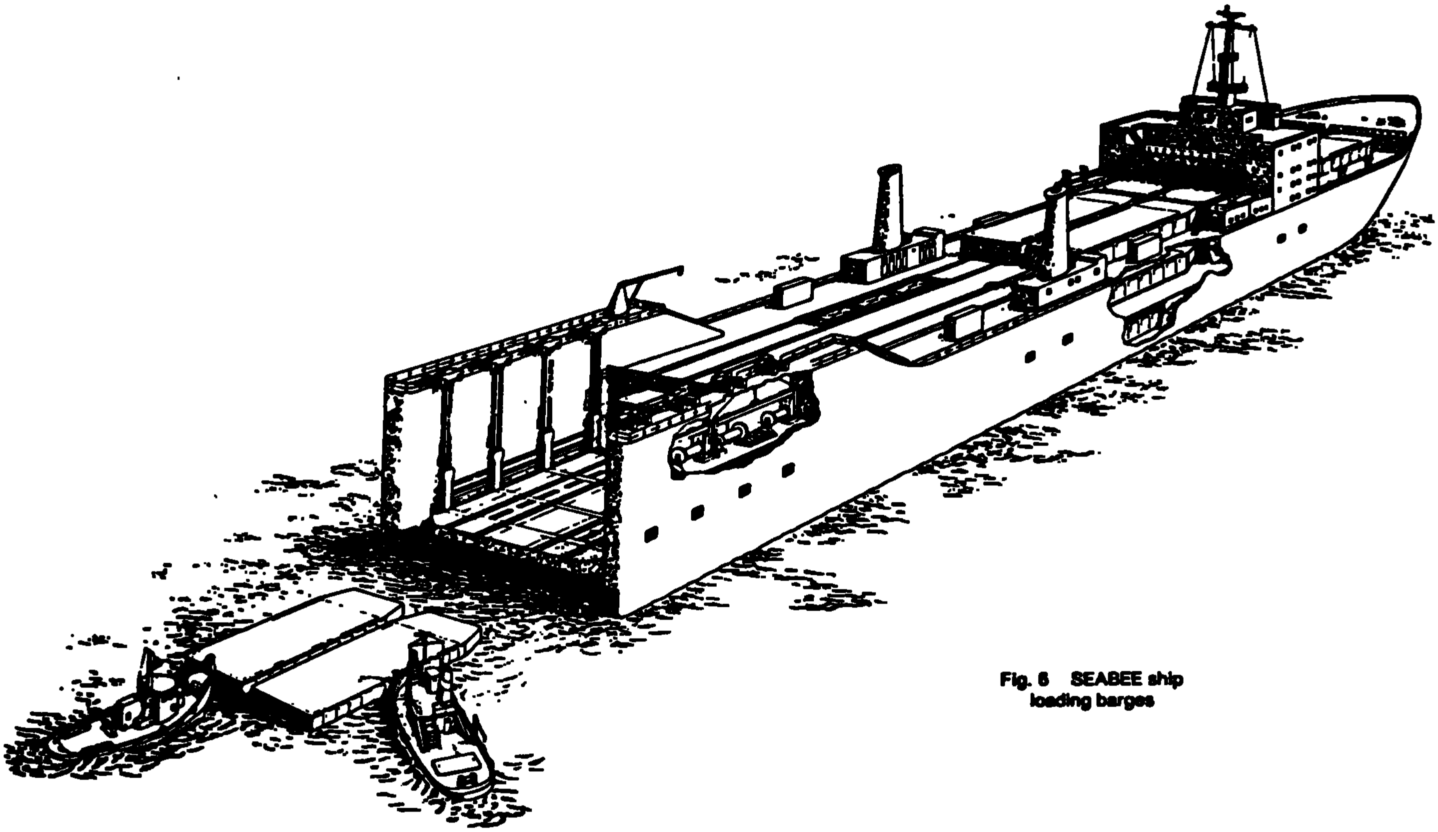


Fig. 6 SEABEE ship loading barges

SLOOP

SHEER. The longitudinal curve of a vessel's decks in a vertical plane, the usual reference being to the ship's side; in the case of a deck having a camber, its centerline sheer may also be given in offsets. Due to sheer, a vessel's deck height above the baseline is higher at the ends than amidships.

SHEER STRAKE. The uppermost strake of shell plating or planking that follows the sheer line.

SHELL PLATING OR PLANKING. The plates or planks forming the outer side and bottom skin of the hull.

SHELTER DECK. Formerly, a term applied to a superstructure deck fitted continuous from stem to stern and fitted with at least one tonnage opening.

SHIP RIGGED. See FULL-RIGGED SHIP.

SHORT TON. A ton of 2,000 pounds.

SHROUD: One of the principal members of the standing rigging, consisting of wire rope which extends from the mast head to the ship's side, affording lateral support for a mast.

SINGLE BOTTOM. A vessel in which cargo and other internal spaces extend to the shell at the bottom; without a double bottom.

SKEG. A deep vertical, finlike projection on the bottom of a vessel near the stern, installed to support the lower edge of the rudder, to support the propeller shaft for single-screw ships, and for the support of the vessel in dry dock; also used on barges to minimize erratic steering in seaway.

SLAMMING. Heavy impact resulting from a vessel's bottom forward making a sudden contact with the sea surface after having risen on a wave. Similar action results from rapid immersion of the bow in vessels with large flare.

SLOOP. A fore-and-aft rigged vessel with a single mast stepped well forward. It is characterized by a single headsail jib, a gaff-supported mainsail with boom, and a gaff-topsail.

SMOKESTACK. A chimney through which combustion products are led from propulsion and auxiliary machinery to the weather; also called a funnel.

SPAR DECK. An anachronism used on the Great Lakes to indicate the weather or upper deck; so used because the term main deck is applied to the narrow plating forming the top of the usual side tanks abreast the cargo spaces on typical Great Lakes bulk carriers.

SPEED. For seagoing ships, using nautical charts and celestial navigation, speed is usually expressed in knots, or nautical miles per hour; a nautical mile is one minute of latitude on the earth's surface, or 6,076 feet. On the Great Lakes and inland waterways, speed is usually given in statute miles (5,280 feet) per hours.

SQUARE RIGGED. A ship or mast fitted primarily with square sails. See also SAILS.

SQUATTING. The increase in trim by the stern assumed by a ship when underway over that existing when at rest.

STABILITY. The tendency of a ship to remain upright or the ability to return to her normal upright position when heeled by the action of waves, wind, etc.

STANCHION. Vertical column supporting decks, flats, girders, etc.; also called a pillar. Rail stanchions are vertical metal columns on which fence-like rails are mounted.

STANDING RIGGING. Fixed rigging supporting the masts and other spars. On a full-rigged ship, the standing rigging includes forestays that support the masts in a fore-and-aft direction, shrouds that support the masts in an athwartships direction, and backstays that support the masts both fore-and-aft and athwartships. Other standing rigging of both rope and chain is used to prevent bending of the bowsprit and jib boom under the upward tension of the forestays.

STARBOARD SIDE. The right-hand side of a ship when looking forward. Opposite to port.

STAYS. Fixed ropes leading forward from aloft on a mast to the deck to prevent the mast from bending aft. Backstays lead from aloft to the deck edge well abaft the position of the mast. Preventer stays lead to any point on the deck to provide additional support when handling very heavy loads with boom tackle.

STEERING GEAR. A term applied to the steering wheels, leads, steering engine, and fittings by which the rudder is turned. Usually applied to the steering engine.

STEM. The bow frame forming the apex of the intersection of the forward sides of a ship. It is rigidly connected at its lower end to the keel. On a wooden ship it is formed from a heavy timber; on a steel ship it may be a heavy flat bar or of rounded plate construction.

STERN, CRUISER. A spoon-shaped stern used on most merchant ships, designed to give maximum immersed length.

STERN, TRANSOM. A square-ended stern used to provide additional hull volume and deck space aft and (or) to decrease resistance in some high-speed ships.

STERN FRAME. Large casting, forging or weldment attached to the after-end of the keel. Incorporates the rudder gudgeons and in single-screw ships includes the propeller post.

STERNPOST. Sometimes, the vertical part of the stern frame to which the rudder is attached on a steel ship. On a wooden ship, a heavy vertical timber, attached to the keel, and forming the aftermost termination of the lower hull.

STIFF, STIFFNESS. A vessel is said to be stiff if she has an abnormally large metacentric height. Such a ship may have a short period of roll and therefore will roll uncomfortably. The opposite of TENDER.

STOW. To put away. To stow cargo in a hold.

STOWAGE FACTOR. The volume of a given type of cargo per unit of its weight.

STRAKE. A continuously joined line of planks or plates running fore-and-aft that makes up one level of the shell of a ship. The uppermost strake is called the sheer strake. Where the bottom and side are joined is called the bilge strake. And, the strake contiguous to the keel is called the garboard strake.

STRENGTH DECK. The deck that is designed as the uppermost part of the main hull longitudinal strength girder. The bottom shell plating forms the lowermost part of this girder.

STRUT. Outboard column-like support or vee-arranged supports for the propeller shaft, used on some ships with more than one propeller instead of bossings.

STUFFING BOX. A gland or seal through which passes a rotating shaft. The purpose of the stuffing box on the main propulsion tailshaft, for example, is to keep water from entering the ship through the sterntube while applying to the shaft a minimal torsional friction loading. The term can also be applied to seals around reciprocating shafts.

SUPERSTRUCTURE. A decked-over structure above the upper deck, the outboard sides of which are formed by the shell plating as distinguished from a deckhouse that does not extend outboard to the shell.

S.W. An abbreviation for salt water or sea water, generally assumed to have a specific gravity of 1.025, a density of 64 pounds per cubic foot, and a volume of 35 cubic feet per long ton.

TAILSHAFT. The aftermost section of the propulsion shafting, in the stern tube in single-screw ships and in the struts of multiple screw ships, to which the propeller is fitted.

TANK TOP. See INNER BOTTOM.

TILLER. An arm, attached to the rudder stock, which turns the rudder.

TONNAGE. Displacement tons are long tons of 2,240 pounds that represent the weight of water that the vessel displaces, i.e., the actual weight of the entire vessel including the load it is carrying. The carrying capacity of a vessel can be expressed either in weight units or volume units. The carrying capacity in weight units is the deadweight tonnage (DWT) expressed in long tons (for inland waterways vessels, short tons of 2,000 pounds are usually used for both displacement and deadweight); the deadweight plus the lightship weight equals that full load displacement.

As early as 1423, British law required that imported wine be carried in casks which were called "tuns." These tuns held about 252 gallons of wine, a weight of about 2,240 pounds. It was the "duty" of the importer to submit to a "tunnage tax" and it was the "custom" of the time for the Crown to assess what this tax should be. In the late seventeenth century, each ship was measured to determine how many tuns it could carry and the result became known as the tunnage or tonnage of the ship.

In 1720, the British Parliament adopted a formula known as the Builders Old Measurement Rule that calculated the deadweight as the length times the square of the beam divided by 188. This was used for taxable tonnage by the British until 1854 and by the United States until 1864 when the Moorsom System was adopted. Generally stated this system involves obtaining the total internal volume of the vessel in cubic feet and dividing this number by 100. The result is roughly the "gross tonnage" or "gross register tonnage" of the ship.

TONNAGE DECK. The deck which constitutes the upper boundary of the internal volume of the measurable portions of the ship as defined by the tonnage regulations.

TONNAGE MARK. A distinctive symbol placed slightly abaft amidships each side indicating the maximum draft to which a vessel may be loaded.

TONNAGE, NET. Net tonnage according to national and canal rules is derived from gross tonnage by deducting an allowance for the propelling machinery space and certain other spaces.

TOPPING LIFT. A wire rope or tackle extending from the head of a boom to a mast, or to the ship's structure, for the purpose of supporting the weight of the boom and its loads, and permitting the boom to be raised or lowered.

TRAMP SHIP. A general breakbulk cargo ship that has no set trade route or schedule.

TRANSOM. The stern, or the aftermost frame, of an overhanging, square ended ship.

TRIALS. Tests that are conducted on a newly built ship to determine whether it meets its design specifications and will satisfactorily meet the requirements of the owner. Often included are DOCK TRIALS to assess the performance of all non-propulsion machinery, SEA TRIALS to test maneuvering and underway speed performance, and STANDARDIZATION TRIALS to evaluate the performance of the first of a class of ships of the same design and to assess how the full scale ship results compare with model tests.

TRIM. The difference between the draft forward and the draft aft. If the draft forward is the greater, the vessel is said to "trim by the head." If the draft aft is the greater, she is "trimming by the stern." To trim a ship is to adjust the location of cargo, fuel, etc., so as to result in the desired drafts forward and aft.

TUMBLE HOME. Inboard slope of a ship's side, usually above the designed waterline, from the waterline in toward the deck.

'TWEEN DECKS. The space between any two adjacent decks.

TWO-COMPARTMENT SUBDIVISION. A standard of subdivision of a ship by bulkheads, which will result in a ship remaining afloat with any two compartments flooded.

ULCC TANKER. An ultra-large crude oil carrier, over about 400,000 deadweight tons.

VLCC TANKER. A very large crude oil carrier, over about 150,000 deadweight tons.

WATERLINE. The line of the water's edge when the ship is afloat; technically, the intersection of any horizontal plane with the molded form.

WEATHER DECK. Uppermost continuous deck with no overhead protection.

WHALEBOAT. A long narrow rowboat with a pronounced sheer and with both ends sharp and raking.

WHERRY. A long, light rowboat, with both ends sharp, used to transport passengers on rivers and in harbors.

WINCH. A machine, usually steam or electric, used primarily for hoisting and lowering cargo but also for other purposes.

WINDLASS. The machine used to hoist and lower anchors.

YARD. A cylindrical spar tapering in diameter from the center toward each end from which a square sail or a lateen sail is hung. On a square-rigged ship the yards are loosely secured to the mast so that they can be raised or lowered by lifts and their angle relative to the ship's centerline can be changed by manipulating the braces.

YAWL. A fore-and-aft rigged sailboat with a mainmast stepped slightly farther forward than a sloop, carrying a mainsail and one or more jibs, and having a small mizzenmast and sail stepped abaft the rudder stock.

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