THE WESTERN RIVER STEAMBOAT:
STRUCTURE AND MACHINERY, 1811 TO 1860

A Thesis
by
ADAM ISAAC KANE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of
MASTER OF ARTS

May 2001

Major Subject: Anthropology
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Approved as to style and content by:

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May 2001

Major Subject: Anthropology
ABSTRACT

The Western River Steamboat: Structure and Machinery, 1811 to 1860. (May 2001)

Adam Isaac Kane, B.A., Millersville University
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The western river steamboat contained the technology that transformed the trans-Appalachian West from a wilderness to an economically significant region of the country. The following study explores the origin and development of this important steamboat type by analyzing archaeological data and historic sources. This information is used to create a thorough study of steamboat construction and machinery.

The first steamboat on the western rivers was built by Robert Fulton in 1811. In the next decade many steamboats followed, but these vessels were not well-adapted to the shallow and swift rivers. Typically these steamboats had deep-drafted, stoutly constructed hulls, heavy low-pressure condensing engines, and many other features akin to ocean-going watercraft. In the 1820s, shipwrights began to adapt steamboat hull form and machinery to the river conditions. By the close of this decade the high-pressure engine was universally adopted for use on western steamboats because of its power, light weight, low cost, and ease of repair. Advancements in propulsion machinery were paralleled by the construction of shallow, flat-bottomed hulls and multiple decks rising high above the waterline. In the late 1830s or early 1840s, the construction of steamboats was materially advanced with the invention of hogging chains. These long iron rods prevented steamboat hulls from hogging or sagging, thereby allowing shipwrights to build vessels with lighter timbers, further reducing vessel draft.
The first section of this thesis introduces the reader to the subject and outlines the sources consulted for this study, while Sections II and III present the historic context necessary for understanding the western river steamboat's historic importance. Sections IV through VI contain a detailed analysis of steamboat structure and machinery divided into chronological periods. Conclusions are presented in Section VII. Appendices include a table quantifying steamboat construction on western rivers and a table of measurements from steamboats that plied the Ohio River in 1850.
DEDICATION

for Andréa
ACKNOWLEDGMENTS

This study of the construction and machinery of the western river steamboat was completed with the support of many individuals, institutions, and organizations. I am indebted to Dr. Kevin Crisman, chairman of my thesis committee, for his expertise and scholarly input in helping me construct this thesis, and his guidance throughout my graduate studies at Texas A&M University. I would like to thank committee members Drs. Charles E. Brooks and C. Wayne Smith for their generous contributions of time and talent to this thesis. I also appreciate the valuable insights and suggestions provided by Drs. Donny Hamilton and Frederick Hocker while compiling this study, and the financial support provided by Texas A&M University's Nautical Archaeology Program.

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I would like to thank the many archivists and librarians who assisted me in this research effort. Foremost among them are Yvonne Knight at the Howard Steamboat Museum and M'Lissa Kesterman at the Public Library of Cincinnati and Hamilton County. I am also indebted to the staffs at the Library of Congress, the National Archives, the Arabia Steamboat Museum, the Lilly Library at Indiana University, and the Sterling C. Evans and Cushing Libraries at Texas A&M University.

I offer a sincere thanks to my family and friends for their constant support: Walter and Lisa Kane, Peggy Kane, Nick Wyatt, Charles Kane, Dan Walker, Erkut ArcaK, Corey Ramsey,
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Finally, I will be forever grateful for the unwavering support of my wife, Andréea. Her patience through this process has been extraordinary, as has her skill in editing the text of this thesis.
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I: INTRODUCTION

I hardly know what to liken them [western river steamboats] to, or how to describe them. In the first place, they have no mast, cordage, tackle, rigging, or other such boat-like gear; nor have they anything in their shape at all calculated to remind one of a boat’s head, stern, sides, or keel. Except that they are in the water, and display a couple of paddle-boxes, they might be intended, for anything that appears to the contrary, to perform some unknown service, high and dry, upon a mountain top.1

For most of the nineteenth century, the western river steamboat was the thread that bound the states and territories of the Mississippi Basin together. In a thousand different ways the steamboat affected the lives of every person in the region. Vast quantities of every good extracted from the western lands were shipped down the Mississippi River to markets the world over; for the upstream journey, manufactured products were packed into every available space in the steamboat’s hull, while on its decks scores of immigrants and travelers saw the country’s interior for the first time. The steamboat was the primary agent in transforming the trans-Appalachian West from a sparsely settled wilderness into an economically significant region of the country.2 The steamboat’s role in shaping the character of the North American continent cannot be overestimated.

Western river steamboats were specifically adapted to the swift currents and widespread bars and shoals of the rivers of the Mississippi Basin. These conditions gave rise to a vessel type distinguished by a shallow, flat-bottomed hull built of light timbers and braced

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1C. Dickens, American Notes and Pictures from Italy, pp.156-157.
by hogging chains. A consequent lack of space in the hull necessitated multiple decks for passenger and cargo accommodation. The development of the steamboat's high-pressure engine occurred in tandem with the structural evolution of its hull and superstructure, in accordance with the natural and human resources of the region at that time. Western rivers were swift and shallow, requiring a powerful and light-weight engine. In the sparsely populated West, industrial centers were separated by hundreds of miles of wilderness; steamboat engines needed to be simple in order to facilitate and lessen the frequency of repairs. The availability of vast tracts of timber and large coal reserves rendered the efficiency of the engines a concern of only minor importance. This steam power plant, therefore, was characteristically light weight, powerful, easy to maintain, and immensely wasteful.

Despite the steamboat's crucial role in western regional development and the uniqueness of its structure and machinery, its creation generated very little contemporary technical literature. The evolution of the steamboat was the result of trial and error by many shipwrights, engineers, and steam engine builders. None of these parties used scale drawings or ship's plans during the construction of steamboats. The cryptic documents preserved in the historical record provide only a partial understanding of the structural and mechanical progression of this vessel type. This thesis seeks to use archaeological data, a previously untapped and significant information source, to more completely understand the structure and machinery of the western river steamboat. While the written record may not shed light on the steamboat's structural details, these details are not lost; they remain buried or submerged in rivers throughout the nation's interior.
This thesis synthesizes the diverse body of archaeological and historical data regarding the machinery and structural elements of the western river steamboat for the years 1811 through 1860. It was during these years that the steamboat was introduced to the western waters, underwent numerous and massive structural changes, and eventually reached the general form it would carry into the twentieth century. This study is a thorough examination of western river steamboat construction and evolution, and results in an analytic framework for archaeological excavations of this vessel type and a foundation upon which other investigations may build. The results are intended not only for nautical archaeologists and maritime historians concerned with the minutia of boat-building, but for anyone interested in further understanding the technological origins of our world today.

THEESIS ORGANIZATION

This study is divided into seven sections. Section I introduces the reader to the topic, delineates the organization of the thesis, and outlines the research sources consulted in writing this work. Sections II and III, the Trans-Appalachian West in the Early Federal Period and the Role of the Steamboat in Western Development, present a broad historical context necessary for understanding the remainder of the thesis. Sections IV through VI, Introductory Phase (1811 to 1820), Developmental Phase (1820 to 1835) and Mature Phase (1835 to 1860), constitute the core of this study. Each section describes the structural and mechanical development of the steamboat within those temporal limits. The conclusions derived from this work are presented in section VII, followed by the Bibliography and a Glossary of specific nautical terms used in this thesis. Appendix I contains a table quantifying steamboat construction on the western rivers between 1811 and 1880, while Appendix II provides a table of measurements from steamboats that plied the Ohio River in 1850.
RESEARCH SOURCES

This thesis represents the results from approximately five years of research and analysis by the author. Many research materials were examined, with primary sources used whenever possible and secondary sources consulted when appropriate. Much of the research was conducted at the Sterling C. Evans and Cushing Libraries of Texas A&M University; this research was complemented by information gathered at several repositories in the Midwest and in the nation’s capitol. Such repositories include the National Archives, the Library of Congress, the Public Library of Cincinnati and Hamilton County, The Howard National Steamboat Museum, and the Arabia Steamboat Museum. The following pages contain a literature review detailing the accumulated data.

Primary Sources

The primary sources consulted for this thesis can be broken down into two broad categories: historical materials and archaeological sites.

Historical Materials. The historical materials gathered for this study were essential for explaining, to the extent possible, the structural and mechanical characteristics of western river steamboats. These records are often fragmentary, but when combined with archaeological data, they allow a more complete understanding of the subject.

Technical Journals. Nineteenth century technical journals proved especially useful in understanding the structure and machinery of western river steamboats. Two features in particular brought the western river steamboat to the attention of engineers and architects: the tendency of western river steamboat boilers to explode, and the uniqueness of the vessel’s design. The Journal of the Franklin Institute was exceedingly informative. This organization conducted a survey of professionals in the steam engineering field through most of the 1830s to determine the cause of and prescribe a cure for boiler explosions. Other journals such as
Marine Engineering, International Marine Engineering, and Transactions of the Institution of Naval Architects provided insights into construction and machinery, often based on the peculiar nature of steamboating on the western rivers.

**Governmental Documents.** Information published by the government regarding western river steamboats can be placed into three categories: Congressional documents, census-related materials, and court cases. Issues relating to western river steamboats were repeatedly debated before the House of Representatives and the Senate during the nineteenth century, especially during the 1830s and 1840s. The issues addressed in this format typically centered on western river navigational conditions and attempts to regulate the inspection and operation of steamboats. The former of these issues was generally brought to the attention of the government by parties with direct interests in clearing the rivers of snags, and promoting commerce. The government also took an active role in investigating the causes of numerous boiler explosions on steamboats, and how best to end these tragic events.

Materials from the 1880 and 1890 U.S. Censuses were useful, especially certain supplemental reports which supplied statistical information. The most enlightening of these was the Report on the Ship-Building Industry of the United States by Henry Hall, compiled for the 1880 Census.

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1See Wicllife, “Navigation Ohio and Mississippi Rivers,” *HD 21st Congress, 1st Session*, 201 (1830); and J. Law et al., “Memorial from a Meeting of Citizens of the West, Held at Evansville Indiana, on the Subject of Western Interest,” *HD 31st Congress, 2nd Session*, 3 (1850).

A United States Supreme Court case from 1850, *The State of Pennsylvania v. The Wheeling and Belmont Bridge Company*, was an invaluable source in writing this thesis. In this litigation, a group of men with interests in steamboating took the Wheeling and Belmont Bridge Company to court over that company’s plan to build a bridge over the Ohio River, thereby obstructing river navigation. Central to the plaintiffs' argument was an explanation of how steamboats were built, the circumstances leading to their unique construction, and why modifying them by lowering their chimneys was not practical. To this end, dozens of shipwrights, steam engine builders, engineers, captains, and steamboat owners were examined and cross-examined, their responses to interrogatories transcribed into the official court records.

**Archaeological Sites.** The following section describes the archaeological sites from which much of the later structural analysis is derived. This data set is not comprehensive. The reader will note that five of the steamboats listed fall outside the temporal criteria for this thesis. Furthermore, there are no currently published materials on investigated steamboats earlier than the Cremona (1852). Although these features of the data set are unfortunate, they do not detract from the wealth of information contained within them or their potential to add to this study. To date, archaeological surveys have been conducted on nine steamers: Cremona (1852), Arabia (1853), Kentucky (1856), A.S. Ruthven (1860), J.D. Hinde (1863), Bertrand (1864), Black Cloud (1864), Caney Creek Wreck (c. 1850-1860) and 3CT243 (c. 1883). The quality and extensiveness of information gleaned from these investigations vary.

*See R. H. Walworth, Order of Reference of the Supreme Court of the United States, in the Case of *The State of Pennsylvania, Complainant, Against the Wheeling & Belmont Bridge Company and Others, Defendants.*
The surveys, ranging from one day inspections to mitigations, from surveys done by professional archaeologists to salves by treasure hunters, form a significant body of data.

_Cremona_. Built in 1852 at New Albany, Indiana, _Cremona_ was a sternwheeler.

The remains of the vessel measured 215ft (65.5m) long, with a beam of 20ft (6.1m) exclusive of the guards. _Cremona’s_ home port was Mobile, Alabama, from which it serviced inland cotton plantations. The vessel was scuttled during the Civil War by the Confederate Corps of Engineers to obstruct the entrance to Mobile Harbor. In 1984, the U.S. Army Corps of Engineers sponsored a cultural resources impact survey in anticipation of dredging activity in the vicinity. In this survey, trenches were excavated in the bow, stern, and amidships; these three exposed areas were documented.

_Arabia_. _Arabia_, a sidewheeler built in Brownsville, Pennsylvania in 1853, had a length of 181ft (55.2m), a breadth of 31ft (9.5m) excluding the guards, and a depth of 5.5ft (1.7m). The vessel snagged and sank in the Missouri River near Kansas City in 1856. The Missouri River subsequently meandered, leaving the vessel buried beneath 42ft (12.8m) of sediment. Though the steamer’s cargo was salvaged by the Hawley family in the late 1980s, the complete collection of artifacts was kept together and is now displayed in the _Arabia_ Steamboat Museum. Little information concerning the construction of the vessel has been published.

_Kentucky_. _Kentucky_ was a sidewheel steamboat built in 1856 in Cincinnati, Ohio. The vessel had a length of 222ft (67.8m), a breadth of 32ft (9.8m) excluding the guards, and a depth of 5.5ft (1.7m). _Kentucky_ saw extensive use during the Civil War and was lost to a snag.

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8See J. Irion, _Archaeological Testing of the Confederate Obstructions_, 1Mb28 Mobile Harbor, Alabama.
9See G. Hawley, _Treasure in a Cornfield: The Discovery and Excavation of the Steamboat Arabia._
in June 1865 near Shreveport, Louisiana. In 1997 an archaeological mitigation under the
direction of the U.S. Army Corps of Engineers was conducted on the aft 30ft (9.1m) of the
hull.\(^\text{11}\) Excavations revealed that the vessel was preserved up to the level of the main deck.

A. S. Ruthven. A. S. Ruthven was a sidewheel steamboat built at Cincinnati in 1860 for
service on the Trinity River in Texas. The vessel had a length of 127ft (38.7m), was 30ft (9.1m)
in beam, and had a depth in the hold of 4ft 8in (1.45m).\(^\text{12}\) In 1872 or 1873, after a long
career, the vessel's machinery was salvaged and the hull discarded in the Trinity River, near
Palestine. A preliminary investigation of the steamboat's remains was undertaken in 1997 by
the Southwest Underwater Archaeological Society and the Texas Historical Commission.
These organizations conducted a two-day assessment of the site, documenting as much of the
wreckage as possible in the available time.

J.D. Hinde. A sternwheel steamboat, believed to be the J.D. Hinde, was
archaeologically investigated on several occasions.\(^\text{13}\) J.D. Hinde, built in 1863 at Portsmouth,
Ohio, spent the beginning of its career plying the bayous of southern Louisiana, until 1869
when it was sold to a group of merchants from Galveston, Texas. The steamboat then worked
on the Trinity River until it was lost to a snag near Liberty, Texas in November 1869. In recent
years the U.S. Army Corps of Engineers sponsored several surveys to document portions of the
vessel's hull.

\(^{11}\)See D. Robinson et al., *Phase III Archeological Investigations of Shipwreck Kentucky (Site 16BO358)*
at Eagle Bend, Pool 5, Red River Waterway, Bossier Parish, Louisiana; and J. Seidel and D. Robinson,
*Phase II Archeological Investigations of Shipwreck Kentucky (Site 16BO358)* at Eagle Bend, Pool 5, Red
River Waterway, Bossier Parish, Louisiana.

\(^{12}\)See C. B. Klopp, A. W. Hall, and J. J. Simmons, *The A.S. Ruthven.*

\(^{13}\)See R. L. Gearhart and S. D. Hoyt, *Channel to Liberty: Underwater Archaeological Investigations,
Liberty County, Texas*; and S. R. James and C. E. Pearson, *Submerged Cultural Resources Investigations
of the Steamboat J. D. Hinde (41LB85), Channel to Liberty, Liberty County, Texas.*
Bertrand. The most informative archaeological investigation of a western river steamboat was that of the steamboat Bertrand, located in the Desoto National Wildlife Refuge near Omaha, Nebraska. The vessel sank on the Missouri River after a snag punctured its hull. Archaeological documentation was undertaken by the National Park Service and the Bureau of Sport Fisheries and Wildlife in conjunction with a group of salvagers. The archaeological excavators, in addition to recovering thousands of items bound for the mining outpost of Fort Benton, documented the well-preserved remains of the vessel's hull.

Black Cloud. Black Cloud, a sidewheel steamboat built in 1864 at Orange, Texas, was used to transport cotton and assorted other goods on the Trinity River. The vessel had a length of 129ft (39.3m), a beam of 33ft (10.1m), and a 4ft (1.2m) draft. The vessel was lost on the Trinity River, near Liberty, Texas. A site survey was undertaken by the Texas Antiquities Committee and Texas A&M University. The survey revealed the vessel had remained largely intact up to the level of the main deck.

Caney Creek Wreck (41MG32). This vessel was a sidewheel steamboat with a preserved length of 128ft (39.0m) and a beam of 24ft (7.3m) excluding the guards. The wreck lay in 12 to 15ft (3.7 to 4.6m) of water in the Caney Creek, a few miles south of Bay City, Texas. It was investigated by a team of trained archaeologists and volunteer divers from the Texas Historical Commission and the Southwest Underwater Archaeological Society. Investigations focused on recording exposed features, resulting in an overall plan view of the remains and more detailed drawings of some of the extant machinery. An investigation of the

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16See D. L. Hedrick, The Investigation of the Caney Creek Shipwreck Archaeological Site 41MG32.
historical record was unable to uncover the exact identity of the vessel, although the characteristics of the machinery give it a terminus post quem of 1845.

3CT243. In the summer of 1988, approximately 4.5 acres (1.8 hectares) of water craft wreckage including two barges, a coal flat, a john boat, and a sternwheel steamboat were documented during a period of low water on the Mississippi River, near West Memphis, Arkansas. The remains of the steamboat, speculated to be the Minnetonka built in 1883 at Jeffersonville, Indiana, were of interest for this study. Minnetonka had a length of 176ft 5 in (53.8m), width over the guards of 35ft 4 in (10.8m), and a depth in the hold of 5ft 4 in (1.6m).

Secondary Sources

During the writing of this thesis, numerous sources containing the research of other authors were consulted. These included scholarly books, theses and dissertations, to more anecdotal works lacking citations or bibliographies. One secondary source proved invaluable to the writing of this thesis: Louis Hunter's well-researched and written Steamboats on the Western Rivers: An Economic and Technological History, published in 1949, which laid the foundation for this study. In this work he analyzes the western river steamboat as a technological instrument and describes nearly all of the pertinent aspects of this vessel type. It is upon Hunter's study that this thesis attempts to build. Hunter delineated the structural and mechanical development of the steamboat, but he lacked archaeological data, which has brought to light many details unknown in 1949.

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II: TRANS-APPALACHIAN WEST IN THE EARLY FEDERAL PERIOD

WESTERN EXPANSION

On July 4th 1803, Thomas Jefferson announced to the American people that their government had purchased the Louisiana Territory. Previously, the nation had spanned from the Atlantic seaboard, across the Appalachian Mountains, to the Mississippi River. This territory alone made the country one of the largest in the world, but with the stroke of a pen a vast new expanse of land, encompassing approximately 900,000 square miles (2,331,002 square km), doubled the size of the United States. Although most Americans believed in the great potential of this new region, the reality was that none of them could make an informed judgement about this terra incognita. The character of the land, its inhabitants, and even its geographic boundaries were largely unknown. Maps of the day showed large vacancies in the central portion of the continent and imaginary geographic features (Fig. 1).

Fig. 1. Map of North America from 1803 showing the Louisiana Purchase (J. Luffman, Geographic Principles, map 1)
From the time colonists first arrived at the Atlantic coast of North America, they had continually pushed the boundaries of European settlement westward. This trend only accelerated in the years following the American Revolution. By the turn of the nineteenth century, small farms dotted much of the territory leading up to the foot of the Appalachian Mountains, with an increasing number of intrepid backwoodsmen, trappers, and farmers cutting out an existence on the western side of this barrier. Statistics from the first census in 1790 indicate the number of American citizens living in the Mississippi Basin at that time did not exceed 200,000; in 1800 this number had grown to 560,000. This population was small in comparison to that of the East. In 1790, not more than 5 percent of the American population lived west of the Appalachian Mountains, while the vast majority still lived within fifty miles of the Atlantic seaboard.

This geographic reality presented conflicting possibilities for the development of the union. On the one hand, the Thomas Jefferson envisioned a republic of farmers, a nation blessed with enough land on which generations of Americans could expand and cultivate. It was to this end that Jefferson signed the Louisiana Purchase, with the hope that such agricultural promise would preclude the development of the antithetical type of state composed of extensive manufacturing capabilities and densely populated cities. This Jeffersonian view of American political economy was a reaction against the overpopulation and perceived societal decline of many European countries. Industrializing European cities had fostered a large population of wage-earning laborers, a situation which Jeffersonians felt it imperative to avoid, especially in light of the democratic nature of the American political

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9T. Allen et al., The Commerce and Navigation of the Valley of the Mississippi; and Also that Appertaining to the City of St. Louis: Considered, with Reference to the Improvement, by the General Government, of the Mississippi River and its Principal Tributaries, p. 4.
system. The Republican view of political economy maintained that moral decay attributed to
the unthinking, landless masses was at odds with the citizenry requirements of a social
democracy, and therefore had the potential to destroy the union. Given these beliefs, the
expansive nation could maintain its revolutionary dream only through population growth
across space, thus limiting the number of landless, dispossessed citizens and avoiding the
degradation of society. 20

On the other hand, many doubted the ability of a democratic government to hold
together such a large and diverse region. 21 The Louisiana Purchase doubled the area of the
United States, further exacerbating the problems of holding together such a large country. The
potential problems associated with territorial expansion were expressed in 1803 by a Senator
from Delaware, Samuel White:

Our citizens will be removed to the immense distance of two or three thousand miles
from the capital of the Union, where they will scarcely ever feel the rays of the general
government; their affections will become alienated; they will gradually begin to view
us as strangers; they will form other commercial connections, and our interests will
become distinct.

These, with other causes that human wisdom may not now foresee, will in
time effect a separation, and I fear our bounds will be fixed nearer to our houses than
the waters of the Mississippi. We have already territory enough. 22

The very sovereignty of the union seemed to rest upon the question of the
government’s ability to bind the republic together in the aftermath of territorial expansion.
Internal commerce and the economic and social interdependence it created seemed the
natural solution to this problem. Complicating if not entirely preventing internal trade,

The Man... His World... His Influence, p. 84.
22S. White, “New, Immense, Unbounded World,” AC 8th Congress, 1st session (1804): 33-34. This quote
excerpted from D. W. Meinig, The Shaping of America: A Geographical Perspective on 500 Years of
however, were the Appalachian Mountains, a 1500 mile-long (2424km) obstruction which stopped people and goods from moving freely between the developed eastern seaboard and newly colonized lands to the west. During the early federal period many Americans acknowledged the value of improved transportation facilities, often known as internal improvements, but actually building the nation's infrastructure proved especially problematic. The high cost and uncertain constitutionality of the federal government's involvement stalled many projects before even a shovelful of dirt was moved. The effect was that at the close of the first decade of the nineteenth century, the East and West were directly linked by only a handful of rough roads and trails across the mountains.

Though internal improvements were not widely implemented in the West in this early period, this region was not without a means of communication and trade. Residents of the trans-Appalachian West had access to a navigable river system of unparalleled dimensions.\textsuperscript{23} The Mississippi Basin is an immense area, roughly 1,500,000 square miles (3,885,004 square km)\textsuperscript{24}, spanning the breadth of the continent between the Appalachian and the Rocky Mountains. Draining this area is the Mississippi River system, which is composed of three major arteries: the Mississippi, the Ohio, and the Missouri Rivers. Feeding into these arteries are thousands of tributaries ranging in scale from intermittent creeks to considerable rivers. Early settlers immediately realized the value of this transportation medium, and consequently built and adapted craft for use on them.

\textsuperscript{23}Cephart asserts that all "Other things being equal, the rapidity with which a new country becomes settled is directly proportional to its supply of navigable waterways." W. F. Cephart, \textit{Transportation and Industrial Development in the Middle West}, p. 57.

EARLY TRANSPORTATION IN THE TRANS-APPALACHIAN WEST

The two primary means of transportation in the trans-Appalachian West during this period were roads and rivers. The most direct links between the East and the West were roads or trails across the Appalachian Mountains. The more indirect but often less taxing route was a circuitous journey down the rivers of the Mississippi Basin to New Orleans. From this port, goods and people made the oceanic journey to the eastern seaboard or any other destination.

Roads

Although traversing the Appalachian Mountains was the most direct route between regions, the roads were frequently in a poor state of repair. Their condition was generally satisfactory in the summer, but during the winter and spring many deteriorated, often becoming impassable.\(^{25}\) Wagon could traverse them only with great difficulty, frequently with a large portion of their merchandise being necessarily carried on the backs of horses.\(^{26}\) Despite the widespread desire for suitable roads, their creation and upkeep often proved prohibitively impractical and costly in regions so distant from population centers.

In addition, transportation via road was exceedingly expensive. The only western goods that were regularly transported to the East in this manner were cattle, hogs, and horses, because they could be driven to market, and extremely valuable goods such as furs that could stand the expense of the overland trek.\(^{27}\)

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\(^{25}\) Lippincott, *A History of Manufactures in the Ohio Valley to the Year 1860*, p. 56.
\(^{26}\) Hall, *Statistics of the West*, p. 225.
River Transportation

Western rivers were generally a more economical means of transport, and numerous types of craft proliferated on the rivers of the Mississippi Basin. Light and easily transportable, birch bark canoes were favored by explorers, while fur traders preferred dug out canoes, also known as pirogues, because of greater carrying capacity.28 Particularly relevant to this research are keelboats and flatboats, which together filled the role of passenger and trade good carrier prior to the introduction of the steamboat in 1811. Both were common on the rivers of the Mississippi Basin during the last half of the eighteenth and first half of the nineteenth centuries, and were invaluable to the settlement of the trans-Appalachian West. In the absence of more efficient means of transportation, they were essential in moving goods and people throughout the region. Their lack of effectiveness in upstream travel hampered profitability, and without the corresponding flow of manufactured goods upstream, the flow of raw materials downstream was continually hampered. In 1817 it was estimated that all of the Mississippi Basin's commerce was carried on twenty flatboats averaging 100 tons (90.9 metric tons) each, and 150 keelboats approximately 30 tons (27.3 metric tons) apiece.29

Flatboats. Flatboats30 were simple boats with boxlike hulls (Fig. 2). These vessels were practical for transporting goods downstream, but their rectangular shape was not conducive

28E. F. Hallet, Ohio and Mississippi River Transportation 1810 - 1860, p. 25.
30The term flatboat is only one of several names for this type of vessel. Flatboats were often referred to based on their point of origin. Kentucky boats, New Orleans boats, and Arkansas boats were common types named after places, while other vernacular terms such as barges, arks, boxes, tobacco boats, and broad-horns were also used. See H. E. Hoagland, "Early Transportation on the Mississippi," JPE 19 (1911).
to upriver travel. Leland D. Baldwin in *The Keelboat Age on Western Waters* describes a flatboat as follows:

The flatboat was built on sills or gunwales of heavy timbers about six inches thick and was strengthened by sleepers. The gunwales were a foot or two high, and on top of them were mortised studs, perhaps three inches thick and four to six inches wide. At the top of these studs were fastened the rafters that were to bear the roof. The planks of the floor were about two inches thick, but the siding boards were of ordinary thickness.¹¹

![Fig. 2. Drawing of a flatboat (Allen, Western Rivermen, 1763-1861, p.117)](image)

Flatboats were well-suited to the settlers' need to ship goods downstream, chiefly to New Orleans. The vessels were of such simple design that their construction required only minimal knowledge. Furthermore, construction materials were inexpensive, and navigating a flatboat took relatively little skill.³² Upon arrival at their final destination, they could be dismantled and sold as lumber. The crew of the flatboat was then left with a 1500 mile (2414km) or more journey, generally undertaken on foot, back to their homes. Interestingly, the successful introduction of steamboats onto western rivers indirectly aided flatboating. First,

³²Haines, *Ohio and Mississippi River Transportation 1810-1860*, p. 28.
steamboats greatly reduced the hardships of flatboat crewmen by transporting them upriver. Furthermore, the steamboat was a catalyst for river improvements, increasing the demand for river commerce and facilitating larger flatboats. These factors worked to economize the labor requirements of flatboating.\textsuperscript{35}

**Keelboats.** Keelboats were long, narrow vessels designed for use on shallow waters (Fig. 3). A keelboat was of a frame-based construction with a rockered keel, and had a cabin that extended the boat's length. Steering was accomplished with a long oar that pivoted on top of the sternpost. Keelboats ranged in length from 40 to 80 ft (12.2 to 24.4 m) and had a breadth of 7 to 10 ft (2.1 to 3.1 m).\textsuperscript{24} Unlike flatboats, keelboats were used for upstream as well as downstream navigation, though they functioned much more efficiently downstream. The process of moving a keelboat against the current was a time-consuming and labor-intensive process, with each vessel crewed by 30 to 40 boatmen.\textsuperscript{35}

![Fig. 3. Drawing of a keelboat being poled (Dunbar, A History of Travel in America, p. 269)](image)


\textsuperscript{24}Baldwin, The Keelboat Age on Western Waters, p. 45.

\textsuperscript{35}J. Hall, Sketches of History, Life, and Manners, in the West, p. 72.
Given the widely varying conditions of the western rivers, a number of techniques were employed to stem river currents. These included sailing, poling, cordelling, and warping. Most keelboats carried one or occasionally two sails, but favorable winds were intermittent at best. More often than not the workload fell on the shoulders of the crew. Poling, the most common method of propulsion, was achieved by several keelboat men setting their poles against the river bottom and walking along the deck's edge from bow to stern. The vessel was propelled one boat length each time they walked end to end in this manner. When the river was too deep to pole, a method called cordelling was used. This involved attaching a rope several hundred or more feet long to the mast of the keelboat. The crew then towed the vessel from the riverbank or a tow path. This technique was limited to areas where the riverbanks were at least moderately hospitable to foot travel. The final method, warping, was used as a last resort. The crew paddled a skiff or small boat upstream, and attached the cordelle to a tree or snag. A capstan or windlass in the bow of the keelboat was used to draw the vessel upriver.36

Steamboats were introduced to the western waters in 1811, with the earliest steamboats having little effect on the region's commerce due to their small tonnage, limited numbers, and operational difficulties. In the early 1820s the structural and mechanical characteristics of the steamboat were adapted for river conditions to the point that steamboats were able to effectively compete with keelboats. Although the steamboats of this era were not particularly efficient or reliable, the slow, labor-intensive process of keelboating could not compete. Keelboats soon yielded to steamboats on the routes they had previously shared, namely the major trunk routes. On these rivers the deep-drafted steamboats encountered few

36Baldwin, The Keelboat Age on Western Waters, p. 65.
obstructions and greater river depths, and were therefore more effective. Thus the keelboat was forced into the only economic niche left, that of the tributaries which steamboats could not yet service.37 Here keelboating survived, albeit with little economic importance, in some locations into the mid-1800s.

WESTERN DEVELOPMENT

During the first decades of the nineteenth century, many citizens of the eastern states were engulfed in a broad societal and economic change now referred to as the Market Revolution.38 In general, the Market Revolution altered the American societal framework from subsistence farming to market-oriented agriculture. Agriculture was transformed from a labor of unending drudgery just to keep alive, to an industry that created a surplus for exchange: work now had the potential to create wealth.39 The chief requisite for participation in this system was the presence of a transportation system by which agricultural products could be efficiently transported to market. Farmers adjacent to the eastern seaboard had advantageous access to population centers along the east coast and in Europe, so were well-suited to participate in this trade. Agricultural producers in the trans-Appalachian West, however, were unable to efficiently transport the yield of their fertile lands to markets in the eastern United States or Europe, and so were little affected by the Market Revolution.

The consequences of this situation were reflected in the small populations of western urban centers. In 1810, the only town in the Mississippi Basin of considerable size was New

39J. O. Appleby, Capitalism and A New Social Order, p. 34.
Orleans. Advantageously located at the mouth of the Mississippi River, most of the West’s exports and imports passed through this seaport; still, it had only 24,562 inhabitants. Pittsburgh and Lexington each had approximately 4,500 residents, and Cincinnati only 2,540. Other future commercial centers such as Louisville, Nashville, Natchez, and St. Louis were but mere villages with about 1000 inhabitants.40

The absence of a market and its consequences were reflected in the statement of Congressman Porter of western New York in 1810:

The great evil, and it is a serious one indeed, under which the inhabitants of the western country labor, arises from the want of a market. There is no place where the great staple articles for the use of civilized life can be produced in greater abundance or with greater ease, and yet as respects most of the luxuries and many of the conveniences of life the people are poor. They have no vent for their produce at home, and being all agriculturists, they produce alike the same article with the same facility; and such is the present difficulty and expense of transporting their produce to an Atlantic port that little benefit is realized from that quarter.41

It was widely observed that the combination of fertile agricultural land with the lack of a market for excess produce made the pioneers indolent and lazy.42 Farmers had no incentive to grow more food than they could consume, a task fulfilled with relative ease. Cultivating additional acreage was futile work which reaped no rewards.

The potential wealth to be gained through exporting western raw materials and agricultural products was apparent; the quantity and quality of these resources, however, were immaterial without the technology to efficiently transport them to market. In the several decades following the Revolution, the essential character of the West had not changed. The region offered backwoodsmen an adventurous life and hard-pressed eastern farmers an opportunity to support a large family, but to those interested in making money, the region had

40 Callender, QJE 17 (1902):121.
42 Lippincott, A History of Manufactures in the Ohio Valley to the Year 1860, p. 58.
little, if anything, to offer. The region's prosperity, or lack thereof, was directly linked to its inability to export agricultural products, or in return receive manufactured goods and outside products such as coffee, sugar, and salt. In essence, the absence of a means of getting western products to market resulted in the region's negligible economic impact on the country as a whole. Contemporaries realized that the settlement and development of the West was dependent on the region's agricultural producers becoming part of an advantageous trade network. With this access and its corresponding monetary return, participants ideally would increase their production of goods for export and purchase a greater quantity of manufactured articles, beginning a "stream of wealth, which will find its source in the increasing quantity and increased value of the products of the fertile and almost boundless west, [which] will flow a swelling tide through every channel of productive industry, trade and commerce."45

43 Callender, QIE 17 (1902):116.
45 T. M. Monroe, Remarks of Thomas M. Monroe, of Dubuque, Iowa, Before the National Board of Trade, p. 16.
III: THE ROLE OF THE STEAMBOAT IN WESTERN DEVELOPMENT

Steam navigation colonized the west! It furnished a motive for settlement and production by the hands of eastern men, because it brought the western territory nearer to the east by nine tenths of the distance. It opened new channels of intercommunication, and new markets for its products. . . . Steam palaces float by scores upon almost every point of the western waters. The western farmer can receive his friend, and ship his wheat and cotton and sugar and corn, by steamers, almost within stones-throw of his granary. Steam is crowding our eastern cities with western flour and western merchants, and lading the western steamboat with eastern emigrants and eastern merchandise. It has advanced the career of national colonization and national production, at least a century!46

Steamboating was introduced to the western waters in 1811 when Robert Fulton built New Orleans along the banks of the Allegheny River in Pittsburgh. His initiative was followed quickly by many other entrepreneurs; at least 60 steamboats were built or were sent to the western rivers between 1811 and 1820.47 Yet these early steamboats had little impact on the region's commerce. They lacked the hull form and powerful machinery necessary to stem the currents of the western rivers, hence they could not effectively convey the commerce of the West. In the following two decades, however, steamboat construction, from the keel to the pilot house, was completely adapted to the peculiarities of the trans-Appalachian West.

Many of these adaptations were direct reactions to the shallow, swift waters of the western rivers; however, additional factors figured into this development. The region's human and natural resources influenced both the evolution of the steamboat and the steamboat's role in the region's development. Through much of the nineteenth century, the trans-Appalachian West consisted of a dispersed series of settlements separated by hundreds of miles of wilderness. This low population density resulted in a general lack of manpower, and skilled labor in particular was very difficult to find outside of a few isolated towns. By contrast, the

natural resources of the region were seemingly endless. Vast tracts of old growth forest existed throughout the West, and abundant supplies of coal and iron were readily available in the upper Midwest. Given these conditions, steamboats evolved into lightly built, shallow draft vessels propelled by powerful machinery. This machinery was simple in its construction and maintenance, essential qualities given that steamboats were often far from the machine shops and foundries found in urban centers. The building and operation of these vessels consumed vast amounts of natural resources, but the availability of prodigious tracts of timber and large coal reserves rendered efficiency a secondary consideration.

The steamboat's physical adaptation to the western environment forged it into the principal tool used to settle and develop the trans-Appalachian West. For the first time in this region's history, a technology provided rapid transportation for people and goods. Not only was travel by steamboat swift, but the extensive navigable river system of the Mississippi Basin provided a ready-made network for linking the commercial centers of the West with the rest of the nation. Steam navigation brought with it the motive and means for industrialization by facilitating trade between distant population centers, and by providing a vehicle for transporting the region's natural resources. The steamboat's ability to cost-effectively move trade goods provided the first stimulus toward the capitalization of the region's natural resources. No other instrument proved so efficient in effecting the prosperity of the West.

Steam technology was not the only factor leading to the region's rapid development during the first half of the nineteenth century. Other regional and national characteristics helped create a favorable environment for the European American population in the trans-Appalachian West to participate in the national and world economies. Factors such as the nation's growing influx of immigrants, increasing population pressure in the eastern states
forcing many people to seek an existence in the less populated West, and the region's fertile and abundant agricultural land and large timber and coal reserves all strongly influenced the nature and course of the West's development. The steamboat, however, was the critical spark igniting that region into industrial and agricultural prominence. These regional characteristics would have been inconsequential without the benefits afforded by the steamboat.

The primary influence of the steamboat was its facilitation of trade. The steamboat's ability to ply the western rivers provided a transportation medium by which the market economy could take hold in the trans-Appalachian West. The increase in the region's trade and the resulting economic expansion were, however, only the initial consequences of steam navigation on the western waters. A range of secondary effects stemmed from this initial stimulus. Steamboat commerce both spurred the expansion of western urban centers and increased the population density of the region as a whole. For one, it provided a new means by which immigrants could travel into the Mississippi Basin; the steamboat limited the grueling overland journey that formerly was required. Furthermore, the construction and operation of steamboats gave the region a new enterprise requiring goods and services from a variety of other industries, employing tens of thousands.

WESTERN RIVERS

The rivers of the Mississippi Basin admitted steamboat navigation on 15,000 to 20,000 miles (24,139 to 32,185km) of water (Fig. 4). The exact navigable mileage on the Mississippi River and its tributaries varied according to the season, the year, and the meandering courses of its constituent rivers. In 1848, Stephen Long calculated the aggregate extent of navigable

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48C. W. Ward, "Shallow-Draught River Steamers," *TSNAME* 17 (1909): 79. This statistic varies from source to source with the actual navigable mileage varying from season to season and year to year.
waterways to be slightly fewer than 17,000 miles (27,358km), although many rivers in this calculation were only sporadically traveled by steamboats of the smallest class. The details of his examination are presented in Table 1. Regardless of the exact figure, these rivers were unparalleled the world over in terms of the extent of their navigability. That is not to say, however, that their attributes were ideal for steamboat commerce. To understand and appreciate the specific river qualities to which a steamboat had to be adapted, one need only examine the characteristics of these rivers.

Fig. 4. Map showing the western rivers and major urban centers

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<tr>
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<td>Muskingum</td>
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<tr>
<td>Maremec</td>
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<td>Kentucky</td>
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<tr>
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<td>Boggy</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Atchafalaya</td>
<td>360</td>
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</tbody>
</table>
Mississippi River

The navigable length of the Mississippi River was calculated to be approximately 2,000 miles (3,219km), starting at the Gulf of Mexico and ending at the head of navigation, the Falls of St. Anthony in Minnesota. This winding riverine highway was divided into two sections; the lower Mississippi, originating at the river’s junction with the Missouri River near St. Louis, running the entire distance south to the Gulf of Mexico, and the upper Mississippi River north of the Missouri. The lower Mississippi was the trunk route for steamboat traffic; the upper Mississippi was a secondary route. The main tributaries of the Mississippi River were the Missouri, Ohio, White, Arkansas and Red Rivers. Thousands of other tributaries, ranging from intermittent creeks to large rivers, comprised the drainage network of the Mississippi River.

Through much of its course the lower Mississippi River cut through soft alluvial sediments, as it does now, resulting in the river’s tendency to meander. In this process the water flow at the outside of each curve is swifter than that on the inside. With its greater velocity the water at the outside erodes the river bank, while the slower water on the inside of the bend deposits its sediments.59 This results in the river meandering into an ever more crooked form, with the distance between two points via the river normally being more than that by land. When the meandering of the riverbed becomes too extreme, fluvial processes remove the sharp bends from the main river channel via the formation of a cutoff. A cutoff is formed when the river erodes through the remnant of land separating two bends in the river. When the currents connect the two bends, the river is directed away from its former course, cutting part of the riverbed off from the main channel. The part of the riverbed removed from

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the main channel becomes a long narrow lake, known as an oxbow lake. Over time, oxbow lakes fill with sediments until they are indistinguishable from the surrounding land.

As these fluvial processes worked upon the heavily wooded western lands, one effect was that the forests lining the banks of the lower Mississippi River and its tributaries were continually eroded into the river. Great volumes of timber were cast into the river. Timber floating in the river, or driftwood, was a constant annoyance to steamboat captains because it damaged paddlewheels and shortened the life span of steamboat hulls. Driftwood also collected on bars or other obstructions in the river, and as more debris accumulated, an islet in the river, or raft, was formed. In extreme cases, generally on the tributaries of the lower Mississippi River, the stream might be entirely blocked by the raft. These rafts could be many miles long, and delayed the progress of steam navigation on certain rivers.

Driftwood and rafts had the potential to delay steamboats or damage their hulls, but snags were a much greater danger. As a tree floated down river it eventually lost many of its branches, slowly became waterlogged, and in due time was deposited on the riverbed. Frequently the tree’s root mat, weighed down by cobbles and dirt, would sink into the soft bottom sediments, with the remainder of the tree protruding into the water column; thus a snag was formed.\textsuperscript{51} Snags were divided into two types: planters and sawyers. Planters were snags that were so fixed to the riverbed as to be immovable, while sawyers moved up and down in the current.\textsuperscript{52} Either could puncture the hull of a steamboat, causing at best great delay, and at worst the loss of the vessel.

\textsuperscript{51}Hall, \textit{The West: Its Commerce and Navigation}, p. 59
In comparison to many of its tributaries, the lower Mississippi River was deep and presented few impediments to navigation. Although snags were a constant danger, river levels generally permitted steamboat commerce year-round for the waters below Memphis, Tennessee. Above this point navigation was frequently suspended because of low water, often during late summer and in the winter. The delays were an increasingly significant problem farther north due to the smaller drainage area and harsher winters.

The navigational characteristics of the upper Mississippi River differed considerably from those farther south; it was much swifter and shallower. The riverbed of this portion of the upper Mississippi was stable and the river did not tend to meander. The riverbed was characterized by many rocky ledges and bars that were a hazard during periods of low water. Navigation on the upper Mississippi was at least partially obstructed at two locations. The first, known as the Lower or Des Moines Rapids, was a twelve-mile stretch just above Keokuk, Iowa at which the river level dropped 22ft (6.7m). The second obstruction was the Upper or Rock Island Rapids, where the river fell 21ft (6.4m) in 15 miles (24.1km). Both rapids delayed the economic development of the Upper Mississippi Valley.53

Ohio River

The Ohio River, flowing in a southwesterly direction out of Pennsylvania, formed the southern borders of Ohio, Indiana, and Illinois, and the northern borders of West Virginia and Kentucky. Its navigable length was approximately 1,000 miles (1609km), with the main tributaries being the Allegheny, Kanawha, Muskingum, Kentucky, Cumberland and Tennessee Rivers.

53Hunter, Steamboats on the Western Rivers, p. 234.
Navigation on the Ohio River was greatly affected by the seasonal climatic changes of the region, with the prime seasons being fall and spring.\textsuperscript{54} Rivers were raised in the fall by heavy seasonal rains normally beginning in mid-September, although on occasion not arriving until December. These rains swelled the river from its summer drought level to allow navigation along its entire length. Steamboating was generally interrupted for four to eight weeks in the winter due to the river icing over. The length of this delay varied from year to year based on the severity of the winter, with points further south experiencing a shorter interruption. When the ice broke-up, generally in late February, steamboating would again commence.\textsuperscript{55} Spring river levels fluctuated unpredictably based on the thawing of winter snows in the mountains and the frequency of rains. Minor temperature changes or rain storms might cause a freshet, a brief rise in the river; more severe weather oftentimes caused significant floods. The Ohio River typically remained high until about May, gradually diminishing in depth through June, with navigation restricted to only the smallest of steamboats in July, August and September.\textsuperscript{56} These navigation seasons were subject to considerable variation; rain, snow, frost, dry weather, and thaws could each affect the water level.\textsuperscript{57}

The Ohio River for most of its length flowed through an upland area of rolling hills underlain by bedrock. Over the millennia the river cut through this terrain, and consequently its course was constrained, so it did not meander to the extent of the lower Mississippi or Missouri Rivers. Much of the Ohio was bounded by high bluffs, although these banks became

\textsuperscript{54}Walworth, \textit{The Wheeling Bridge Case}, p. 230. This information is taken from the testimony of a civil engineer, Edwin F. Johnson.

\textsuperscript{55}W. C. Lyford, \textit{The Western Address Directory}, p. 84.

\textsuperscript{56}Bernard and Totten, \textit{HD 17th Congress}, 2\textsuperscript{nd} session, 35 (1822): 8.

\textsuperscript{57}Hall, \textit{The West: Its Commerce and Navigation}, p. 53
less pronounced to the south. Due to the stability of the Ohio River’s course, it did not meander through wooded areas. This reduced the number of trees washed into the river, and hence the number of snags in the riverbed. Snags, however, were hardly absent. The semiannual flood often flushed fallen timber downstream, creating on the Ohio the same consequences that befall steamboating on the lower Mississippi River, albeit to a lesser extent.

**Missouri River**

The Missouri River was early recognized as the longest tributary of the Mississippi River, having its headwaters in the Rocky Mountains and eventually flowing through or forming the borders of seven states: Montana, North and South Dakota, Nebraska, Iowa, Kansas, and Missouri. Flowing into the Mississippi River just north of St. Louis, the silt-laden waters of the Missouri River contrast starkly with the comparatively clear waters of the upper Mississippi River. The head of navigation for the Missouri River, Fort Benton, Montana, was a full 3,300 miles (5311km) from St. Louis, and was acknowledged as the world’s farthest port from ocean or sea served by regularly scheduled vessels.59

The conditions of the Missouri River bore many similarities to those of the lower Mississippi. Flowing through a bed of alluvial soil, it was prone to meander and became notorious for its many snags and obstructions. However, the waters of the Missouri were colder, shallower, and more rapid than those of the lower Mississippi River. The Missouri River normally flooded once a year, usually during the summer months as snow in the higher elevations melted.60

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59Hunt, Steamboats on the Western Rivers, p. 229.
60Bernard and Totten, HD 17th Congress, 2nd session, 35 (1822):18
COMMERCIAL IMPACT

The commercial impact of the steamboat first became significant in the 1820s; from that point until the Civil War steam navigation was the dominant transportation medium for the commerce of the trans-Appalachian West. Writing in 1837, James Hall accurately characterized the steamboat's role in the facilitation of trade. He stated "the imported article has fallen in a ratio equal to the increased price of western products. In looking back at the old means of transportation, we cannot conceive how the present demand and consumption could have been supplied by them." George Armroyd in 1830 expressed a similar line of reasoning in a more anecdotal form. He noted that prior to the introduction of steamboats:

Not a dollar was expended for wood in a space of 2000 miles, and the squatton on the banks of the Ohio, thought himself lucky if the reckless boatman would give the smallest trifle for the eggs and chickens, which formed almost the only saleable articles on a soil whose only fault is its too great fertility. Such was the case 12 years since. The Mississippi boats now make five trips within the year, and are enabled, if necessary, in that period, to afford to that trade 35,000 tons. Eight or nine days are sufficient, on the Upper Ohio, to perform the trip from Louisville to Pittsburgh and back. In short, if the steam-boat has not realized the hyperbole of the poet in "annihilating time and space," it has produced results scarcely surpassed by the introduction of the art of printing.  

The steamboat brought every good conceivable to the expanding urban centers and to the increasing number of villages and hamlets growing along the banks of the western rivers. The staples imported to the region were sugar, coffee and molasses; these were supplemented by dozens of other products including cotton, ceramics, hardware, fish, nails, wines and liquors, and soda ash. The goods shipped downstream differed, depending upon the port of origin, although much of the region produced staples such as hemp, corn, whiskey, flour and livestock. Pittsburgh exported large quantities of iron and manufactured articles such as iron

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61 Hall, Statistics of the West, p. 239.
implements and cookware, while Cincinnati became the nation's leader in hog production and processing. St. Louis controlled much of the trade of the Missouri River, with its principal products being pig iron and lead, animal hides and furs, and pork products.  

The number of steamboats and their tonnage increased rapidly after the first quarter of the nineteenth century. In 1880, the Census Office charted the growth of steamboat numbers and tonnage from 1811 through 1880; this chart is presented in Appendix I. These data show that total steamboat tonnage and numbers grew throughout the period, although the business was greatly affected by economic fluctuations, droughts, and floods. In 1820, 15 steamboats were built with a total tonnage of 2,643 (2,403 metric tons), while ten years later 33 were built with an aggregate tonnage of 4,811 (4,374 metric tons). These numbers grew rapidly in the following decades, with 63 vessels having a total tonnage of 9,224 (8,385 metric tons) built in 1840, 109 steamboats of 20,911 gross tons (19,010 metric tons) built in 1850, and 162 steamboats with a cumulative tonnage of 32,432 (29,484 metric tons) constructed in the last year of the antebellum period.  

The growth of steamboating was consistent with that of most new industries; it experienced a period of rapid growth, followed by a period of slower growth, and then finally a sharp decline. The rates of growth for individual steamboats were 360 percent for 1811 - 1820, 199 percent for 1820 - 1830, 140 percent for 1830 - 1840, 96 percent for 1840 - 1850, and 38 percent for 1850 - 1860.  

Steamboat productivity through the century was buoyed by the increasing tonnage of individual steamboats due to advancements in steamboat construction. The effects of these

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69Walworth, *The Wheeling Bridge Case*, pp. 630 and 656.
new construction techniques, primarily those from the use of hogging chains and lighter timbers, can be materially seen in Table 2. The average tonnage of steamboats increased at an even rate, while the cargo capacity greatly outpaced vessel tonnage. In a study of the steamboat's economic impact on the development of the trans-Appalachian West, researchers Erik Haites and James Mak analyzed the productivity of various modes of transportation to determine their relative importance.66 Their evidence showed that the steamboat's productivity between 1815 and 1860 far exceeded that of any other type of transportation for a similar period during the nineteenth century. Furthermore, the success of the steamboat was achieved with little funding from the government when compared with canals or railroads; it was primarily the result of private initiative.67 Hunter asserts that steamboat productivity began to decline in the latter years of the 1850s due to the increasing economic impact of railroads.68 This was at first felt in passenger service and later in freight. Recent studies have shown, however, that prior to the Civil War there was no absolute decline in steamboating; rather steamboating tonnage continued to expand until the start of the Civil War.69

Table 2. Steamboat tonnage and cargo capacity in the ante-bellum period (Haite, Ohio and Mississippi River Transportation 1810-1860, p. 133).

<table>
<thead>
<tr>
<th>Period</th>
<th>Average Measure Tonnage (Tons)</th>
<th>Ratio of Carrying Capacity to Measured Tonnage</th>
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<td>110</td>
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<td>1820 to 1829</td>
<td>290</td>
<td>.80</td>
<td>232</td>
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<td>1830 to 1839</td>
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<td>1.00</td>
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<tr>
<td>1840 to 1849</td>
<td>310</td>
<td>1.60</td>
<td>496</td>
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<tr>
<td>1850 to 1860</td>
<td>360</td>
<td>1.75</td>
<td>630</td>
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68Hunter, Steamboats on the Western Rivers, pp. 492-494.
69Haites, et al., Western River Transportation: The Era of Early Internal Development, 1810-1860, p. 120.
The Steamboat and the Cotton Economy

The commercial impact of the steamboat was not limited to the trans-Appalachian West; its import was felt nationally and internationally. The western river steamboat was one of the key links in a trade network that by the 1840s had formed the backbone of the American economy. During the first decades of the nineteenth century, the nature of the American economy began to change, with a decreasing reliance on international trade and a corresponding growth in domestic trade. This change was largely based on two factors: the development of steamboats that could effectively ply the western waters, and the extension of the cotton culture in the South. Thus began a long period when the enterprise and capital of the country was diverted from foreign commerce into the exploitation of human and natural resources within the nation.

The dominant export of the United States during much of the nineteenth century was cotton. Cotton’s unique cultivation requirements created a circular trading pattern among the nation’s three regions. At the core of the cotton economy was the labor of African American slaves. To ensure efficiency, slave labor was carefully supervised, therefore maximum returns on labor were derived from crops conducive to close labor organization. For this reason, agricultural regions reliant on slave labor devoted themselves to the production of one or two staple crops, such as cotton, sugar, tobacco or rice. The products needed to

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70 Callender, Q/E 17 (1902): 124 and 129-130.
71 See North, The Economic Growth of the United States 1790-1860, pp. 75 -100. Cotton constituted 39 percent of the value of U.S. exports between 1816 and 1820, 63 percent from 1836 to 1840, and approximately 50 percent up to the Civil War (North, The Economic Growth of the United States 1790-1860, p. 75.)
operate slave plantations, such as manufactured goods, and to a lesser extent, food, were purchased from free labor regions.\textsuperscript{72}

The lack of foodstuffs and manufacturers created an interregional trade within the United States among the North, South and West. The South shipped its agricultural exports of cotton, tobacco, sugar and rice to the North, foreign ports, and to a lesser extent upriver to the West. Services such as banking, insurance, brokerage, and transportation were provided to the South by the North. The North also shipped domestic and foreign manufactured goods to the South and the West. The West produced and shipped foodstuffs to the South. During the 1830s this pattern altered slightly as more western produce was shipped to the North using the new east-west links provided by canals and railways.\textsuperscript{73}

The western river steamboat figured heavily in this trade. The transportation of cotton was entirely dependent on the meandering rivers of the Mississippi Basin. Although cotton was a valuable product, it was bulky and difficult to ship overland. Most cotton plantations were but a few miles from the nearest steamboat landing where the cotton was loaded onto the steamboat and shipped to market (Fig. 5). At the same time the steamboats delivered manufactured goods from the North and foodstuffs from the West. As the trade of the West shifted toward the North in the 1830s, the steamboat was still a dominant carrier. Although the steamboat did not take the products of the West to their final destination, it was essential in getting goods to a railhead or to the start of a canal.

\textsuperscript{72}Callender, QJE 17 (1902):126.

\textsuperscript{73}North, The Economic Growth of the United States 1790-1860, p. 102.
POPULATION INCREASE

The increase of commerce in the trans-Appalachian West brought with it a population surge. Not only did the western river steamboat facilitate the commercial development of the West, thereby encouraging settlers to migrate, but settlers more often than not arrived via steamboat. Population increase in the trans-Appalachian West during the nineteenth century was nothing short of astounding. Nationally, the population grew from 5,306,000 in 1800 to 23,192,000 in 1850, a rate of 33 percent each decade.74 This rate far exceeded any other large region of the world, but the population growth of the trans-Appalachian West eclipsed even this extraordinary rate. The population of the region increased from 560,000 in 1800

74Meinig, Continental America, 1800-1867, p. 222.
to 10,520,000 only 50 years later.\textsuperscript{75} Based on these data from the national census, the average increase per decade was 182 percent. Urban centers, particularly those along major waterways, reflected this massive growth. From 1820 to 1850, the population increased from 9,600 to 115,000 in Cincinnati, from 4,000 to 43,000 in Louisville, from 4,900 to 77,000 in St. Louis,\textsuperscript{76} and from 4,768 to 46,601 in Pittsburgh.\textsuperscript{77}

The steamboat was instrumental in transporting immigrants, both Americans and foreigners, to the Mississippi Valley. By lessening or eliminating the long overland migration, the steamboat eased the burden of relocating to a new region. Writing in 1888, J. L. Ringwalt described the scene on board a steamboat.

Immense numbers of passengers are carried from one part of the valley to another by these boats. Those boats which come up from New Orleans bring, besides merchants and other inhabitants or strangers, who occupy the cabin, hundreds of Germans, Irish, and other foreign emigrants of the valley of the Mississippi. On the other hand, those which descend from Pittsburgh carry hundreds of travelers and emigrants from the east, as well as from foreign lands.\textsuperscript{78}

For most immigrants the steamboat was only one stage of a journey that encompassed several transportation mediums. An oceanic journey prior to arrival in the West was common, as was an extended trek via wagon or stagecoach.

For persons traveling overland from the east coast across the Appalachian Mountains, the sight of a western river steamboat was often a bemusing one. Completing the journey overland to Pittsburgh in 1838, David Stevenson noted the city's effect upon the first-time visitor:

\textsuperscript{75}Allen et al., \textit{The Commerce and Navigation of the Valley of the Mississippi}, p. 6. The population of the valley of the Mississippi in 1800 did not exceed 200,000. In 1800 it increased to approximately 560,000, in 1810 to 1,370,000, in 1820 to 2,580,000, in 1830 to 4,190,000, in 1840 to 6,370,000, and in 1850 to 10,520,000 (Allen et al., \textit{The Commerce and Navigation of the Valley of the Mississippi}, p. 4.)
\textsuperscript{76}Callender, \textit{QJE} 17 (1902): 130.
\textsuperscript{77}Hunter, \textit{Steamboats on the Western Rivers}, p. 30.
\textsuperscript{78}Ringwalt, \textit{Development of Transportation Systems in the United States}, p. 114.
Here, in the very heart of the continent of North America, the appearance of a large shipping port, containing a fleet of thirty or forty steamers moored in the river, cannot fail to surprise him; and his astonishment is not a little increased if he chances to witness the arrival of one of those steamers, whose approach is announced long before it makes its appearance by the roaring of its steam, and the volumes of smoke and fire which are vomited from the funnels; but his wonder only attains its height when he is told that this same vessel has come direct from New Orleans, in the Gulf of Mexico, and that fifteen days and nights have been occupied in making this inland voyage, of no less than two thousand miles, among the meanderings of the Mississippi and Ohio.79

ANCILLARY INDUSTRIES

The construction and operation of steamboats spawned a number of ancillary industries important to the industrial development of the trans-Appalachian West. The growth of these industries was aided by the relative geographic isolation of the region. The Appalachian Mountains were an impediment which raised the cost of northern manufactured goods, thereby fostering industry in the West.80 The trade barrier, which only a few decades earlier had hindered the trans-Appalachian West’s development, was turned from a ruinous obstruction into a defacto taxation on goods from more developed areas. The initial stimulus providing a foothold for western industry was the steamboat. The three supplementary industries most affected by the steamboat were shipbuilding, foundry work and lumbering.

Hall estimated that in 1832 the commerce of the western rivers gave employment to 16,900 men: 1,700 shipwrights, joiners, and laborers to build steamboats, 4,400 wood cutters, 4,800 steamboat crew members, and 6,000 persons employed to build and navigate flatboats. To this number must be added the persons who were not directly employed, but who were engaged in ancillary fields such as building machinery, and those involved with furnishing, supplying, loading, and discharging boats. Hall supposed the total number of persons deriving

79Stevenson, Sketch of the Civil Engineering of North America, p. 76.
80Hunter, Steamboats on the Western Rivers, p. 31.
an existence from western navigation to be approximately 90,000. These numbers would continue to grow during the antebellum period.

Steamboat Building

Although steamboat building did not start in the West until 1811 with the construction of New Orleans in Pittsburgh, shipbuilding was already a well-established trade by that time. The construction of keelboats required the skill of trained shipwrights, and shipyards in Pittsburgh built several oceangoing vessels in the late eighteen and early nineteenth centuries. Shipbuilding centers throughout the nineteenth century consisted of Pittsburgh, Cincinnati, and Louisville; however, shipyards in smaller towns, especially along the Ohio River, regularly built vessels. Wheeling, Marietta, Shousetown, Steubenville, Gallipolis, Portsmouth, Ironton, Ripley, Freedom, Beaver, and Madison all built steamboats, although no more than two or three each per year. Outside the Ohio Valley the only building center of significance was St. Louis. This city built very few vessels before 1840, but in the following decades it became the West’s fourth-ranking construction center. During the years 1846, 1848, and 1850 an aggregate 437 steamboats were built in the West, compared with 608 total in the United States during that period. Fully two thirds of the steamboats built in the United States during these years were built in the West. Figure 6 is a chart showing the numbers of steamboats built in the West between 1811 and 1880.

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82Hunter, Steamboats on the Western Rivers, p. 107.
83Law et al., HD 31st Congress, 2nd Session 3 (1850):5
Steamboat construction was a complicated affair requiring three or four different companies. The construction of the vessel’s hull and the framing of its upper works was undertaken by a shipyard (Fig. 7). Often these shipyards were in urban centers, but it was common for hulls to be built in isolated areas and upon completion be floated down river to industrial centers. Another firm then took in the hull and fitted it with steam machinery. The upper works were completed and finished out by one or more firms in charge of carpenters, joiners, gilders, glaziers, glass suppliers, sheet metal workers, and millwrights.

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Foundry Work

Steamboats required vast amounts of iron, not only for steam machinery, but also for fastenings, hogging chains, anchors, and capstans. The abundance of iron ore in the Ohio Valley was the most significant reason for that area's prominence in building steamboats. Timber supplies were extensive throughout the region, but the iron ore of the Ohio Valley ensured that steamboats could be built more cheaply there than in any other location. From its earliest days the iron industry in the West was helped by the expense of transporting the heavy material overland from the North or up the Mississippi River. In 1820 the cost of transporting a ton of goods from Philadelphia to Pittsburgh was between $100 and $150.65 As iron foundries multiplied and expanded along the banks of the Ohio River, especially in Pittsburgh and Cincinnati, the cost of iron rapidly dropped. In the years 1818-1820, bar iron

65Could, Fifty Years, p. 162.
sold for $190 to $200 a ton, while in 1831, with the creation of numerous foundries in Pittsburgh, it sold for $100 a ton.86

**Lumbering**

The lumbering industry was critical to the construction and operation of steamboats. The trans-Appalachian West throughout much of the nineteenth century had an abundant supply of timber. Especially common was white oak for steamboat hulls and white pine for decking and upper works. Hall states that even as late as 1850 the banks of the Ohio River were covered by a dense hardwood forest interrupted only by scattered towns.87 Wood was so inexpensive that the timber required for vessels of comparable dimension cost twice as much in Europe as in America.88 Not only was timber needed for shipbuilding, but western river steamboats burned primarily wood. On the Ohio River, in proximity to large fossil fuel reserves, coal was burned with wood, but on most of the rivers of the Mississippi Basin wood was the sole fuel.

Steamboat building required immense amounts of timber. The amount of wood used in the construction of each vessel varied depending on the particular shipyard and size of the vessel. Figure 8 is a photograph of the Howard Shipyard in Jeffersonville, Indiana showing the wood stored at this shipyard. According to the 1880 census, the shipyard at Sewickley, Pennsylvania in the construction of vessel hulls between 180 and 260ft (54.9 to 79.3m) long consumed 100,000 to 225,000ft (30,480 to 68,581m) of oak, pine and poplar.89 Based on Hall's calculations, this equates to approximately 20 to 50 old-growth trees for the construction

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88Ibid., p. 243.
89Ibid., p. 188.
of each hull. The economic stimulus provided by this new industry was noted in the *Journal of the Franklin Institute* by an unknown author in 1834:

The immense forests of beech and other timber unfit for agricultural purposes, were, before, not only useless, but an obstacle to the rugged farmer, who had to remove them before he could sow and reap. The steamboats, with something like magical influence, had converted them into objects of rapidly increasing value. He no longer looks with despondence on the denseness of trees, and only regrets that so many have already been given to the flames, or cast on the bosom of the stream before him.⁹⁰

![Image](fig8.jpg)

**Fig. 8.** Photograph of the Howard Ship Yard showing the vast amount of timber needed for the construction of steamboats (courtesy of the Howard National Steamboat Museum)

While the construction of steamboats devoured tremendous quantities of timber, the amount of wood needed to fuel the steamers was even more staggering. The demand for fuel fostered thousands of woodlots along all of the navigable rivers of the Mississippi Basin, a weighty source of revenue for citizens of the region. In 1850, the largest class of Ohio River packets consumed between 50 and 75 cords of wood and 3,000 to 4,200 bushels (105,634 to 147,887 l) of coal in a round trip voyage of approximately 1,000 miles (1609 km) between

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Pittsburgh and Cincinnati. In his travels in 1858 Charles Mackay describes the common sight of a woodlot:

On either bank of the Mississippi, as the traveller [sic] is borne down its steady current, he may observe at every four or five miles' distance piles of wood. These are cut... and heaped near the shore for the convenience of the steamers. When a steamer requires wood, it touches at any one of these points, takes what it wants, and either leaves the money or a note of what had been taken, to be settled hereafter. To expedite the process of taking on fuel, wood was frequently stored in flatboats moored to the riverbank. If a steamboat was ascending the river, it needed merely to take the flatboat in tow and transfer the wood to the steamboat while in motion. After being unloaded, the flatboat would be cast off and left to drift back to the woodlot. For the downstream journey, the steamboat would tie up to the riverbank next to the woodlot while the crew and deck passengers loaded the fuel.

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91Walworth, The Wheeling Bridge Case, p. 220. This information was compiled by Mr. Charles Ellet, Jr.
93Walworth, The Wheeling Bridge Case, p. 446.
IV: INTRODUCTORY PHASE (1811 TO 1820)

Examination of this early stage of steamboat development is particularly difficult because the vessels of this era had no definitive typological distinctions. When steam navigation was introduced to the western rivers in 1811 it was an unrefined science; the extensive process of trial and error, design and redesign had just begun. Consequently, there was very little uniformity in hull construction, superstructure, or machinery among these early steamboats. The diversity in steamboat types can be attributed also to the widespread geographical origins of the vessels and machinery: vessels were built on the east coast and imported to the West, machinery of eastern manufacture was installed on hulls built in the West, and vessels and their machinery were built entirely in the West.

The lack of common features within this class of steamboats has led to the structure of the following discussion. Described below are eight individual steamboats to which significant mechanical or structural innovations can be attributed. The discussion of these steamboats will underscore the range of steamboat designs fostered during this early experimental period. The reader will note that this is not a strict progression of all the earliest steamboats on the western rivers; rather it is an analysis of key individual steamboats. This section will be followed by conclusions about the structural and mechanical characteristics of this diverse group of steamboats.
INDIVIDUAL STEAMBOATS

Steamboating was introduced to the western rivers in 1811 when Nicholas Roosevelt, under the direction of Robert Fulton and Robert Livingston, built the steamboat New Orleans. They chose Pittsburgh, a city already established as the industrial center of the trans-Appalachian West, in which to embark on this experiment. Even with Pittsburgh’s growing industrial infrastructure, skilled labor, in the form of shipwrights and machinists, had to be brought in from New York City.\textsuperscript{94} The keel was laid next to Beelen’s foundry on the banks of the Allegheny River; however, most, if not all, of the machinery was cast or forged in New York City.\textsuperscript{95} New Orleans had a length of 116ft (35.4m), a beam of 20ft (6.1m), a depth of 7ft (2.1m), and was powered by a low-pressure condensing engine with a 34in (.86m) cylinder.\textsuperscript{96} The vessel was fitted with two cabins containing four berths, and was equipped with two masts to augment the steam engine.\textsuperscript{97} The cost of its construction was approximately $38,000. Roosevelt steamed New Orleans from its home port down the Ohio and Mississippi Rivers, arriving at New Orleans in January 1812. After its initial voyage it was employed in the New Orleans to Natchez trade, because the shallow waters above Natchez prevented it from ascending beyond that point. Figure 9 shows a contemporary drawing of Fulton’s steamboat Paragon, built on the Hudson River the same year New Orleans was built on the Allegheny River. Although Paragon was a larger vessel, the steamboats had many similarities such as below deck cabins, auxiliary sails, diminutive paddlewheels, and low-pressure condensing engines.

\textsuperscript{94}J. Latrobe, The First Steamboat Voyage on the Western Waters, pp. 11-12.
\textsuperscript{95}Morrison, History of American Steam Navigation, p. 192.
\textsuperscript{96}Latrobe, The First Steamboat Voyage, p. 12.
\textsuperscript{97}Morrison, History of American Steam Navigation, p. 190.
Prior to building New Orleans, Robert Fulton had established himself as America's leading steamboat builder and promoter of steam navigation. In 1807, he oversaw the construction of the North River Steamboat. Although not the country's first steamboat, this vessel is widely acknowledged as the first commercially successful steam-powered vessel. Fulton built his first steamboats on the waters of the Hudson River; however, he understood that in the years to come steam navigation on the western rivers would be economically more important and profitable than on the less extensive eastern rivers. To this end, he built his early steamboats with flat bottoms and vertical sides, under the presumption that this hull form would best suit the shallow waters of the western rivers. Interestingly, after some experience with this hull type he was apparently dissatisfied with its characteristics, because his later
steamboats had hulls more like those of seagoing ships. New Orleans' hull was built like those of ocean-going ships, despite its intended use on the shallow western rivers.\textsuperscript{98}

During the early development of steam technology, monopolies granting exclusive steam navigation rights were routinely awarded by the states to entrepreneurs. The intent was to encourage experimentation in this new and untested field by guaranteeing profits, to the extent possible, if the venture succeeded. Fulton and Livingston had previously received rights to the exclusive use of steam navigation on the waters of New York State, and attempted the same for the states and territories bordering the western rivers. They petitioned the legislatures of Ohio, Kentucky, Tennessee, and the Upper Louisiana Territory.\textsuperscript{99} These were largely rejected, with the exception of Louisiana. Here they were granted exclusive privileges, much to the aggravation of residents in areas to the north. The northern states and territories viewed this act by Louisiana as adversely affecting the navigation of the entire Mississippi Basin, since Louisiana contained the port of New Orleans, the entrepôt which collected nearly all of the West's trade. Restrictions on steamboating at the entry point and terminus for all the region's trade could have been detrimental to all upriver areas, but other entrepreneurs ignored the monopoly and numerous steamers plied the western rivers in this period. The Fulton-Livingston monopoly was officially lifted in 1824 with the Supreme Court case Gibbons v. Ogden.

Few, if any, of these first steamboats functioned well on the western rivers, a problem that did not go unobserved by contemporaries. Many western writers expressed doubt as to

\textsuperscript{98} Hunter, Steamboats on the Western Rivers, p. 67. See also J. B. Marestier, Memoir on Steamboats of the United States of America, p. 7.

\textsuperscript{99} Hunter, Steamboats on the Western Rivers, p. 9.
the potential of steamboats to ever ascend the rapid currents of the western rivers. Writing in 1830, George Armroyd reflected on this period:

> The writer of this well remembers, that in 1816, observing, in company with a number of gentlemen, the long struggles of a stern-wheel boat to ascend Horse-tail ripple, it was the unanimous opinion, that “such a contrivance” might conquer the difficulties of the Mississippi, as high a Natchez, but that we of the Ohio must wait for some more happy “century of inventions.”

The second steamboat on western waters was the diminutive sternwheeler Comet, built in 1813. Comet had a length of 52ft (15.9m), a beam of 8ft (2.4m), and was 25 tons (23 metric tons) burden. This vessel was built in Brownsville, Pennsylvania with an engine based on a patent granted to Daniel French in 1809. This patent was for an oscillating high-pressure steam engine for propelling boats. This was the first use of a high-pressure engine on the western rivers (Fig. 10). Comet made several journeys between Natchez and New Orleans, ignoring the Fulton-Livingston monopoly, but the machinery apparently did not function well. After less than one year of service the engine was removed and sold to either a cotton gin or a saw mill.

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Vesuvius (Fig. 11), built in 1814 at Pittsburgh by Robert Fulton, was the third vessel to ply the western waters. It had a length of 160ft (48.8m), a beam of 30ft\(^{105}\) (9.1m), and drew 6ft (1.8m) of water loaded.\(^{106}\) The vessel was powered by a low-pressure condensing engine of unknown origin.\(^{107}\) A square sail in the bow augmented the steam power plant. The machinery was placed in the hold about amidships, while the area abaft was used for cargo. Passenger quarters were located in a quarter deck, 8ft (2.4m) high and 60ft (18.3m) in length. Above the quarter deck was a promenade shaded by a canopy. A detailed account of this

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\(^{107}\)Morrison, *History of American Steam Navigation*, p. 218. This information is from a letter written by Vesuvius’ agent Jasper Lynch in 1836. Vesuvius caught fire in New Orleans in 1816; it is unclear if the vessel was rebuilt or if an entirely new vessel bearing the same name was constructed.
steamboat comes from the journey of Edouard de Montulé, who traveled on the vessel in either 1816 or 1817.

Fig. 11. Vesuvius on the Mississippi River (Montulé, *Travels in America* 1816-1817, p. 102)

Although not explicitly stated, Montulé’s description reveals that *Vesuvius* was propelled by a low-pressure engine. ¹⁰⁶ Figure 12 is a schematic of the type of engine used on Fulton’s steamboats which parallels Montulé’s description.

The water is contained in a large boiler, filled half full. A fire is built beneath, and the steam, seeking an outlet, rushes into a cast-iron pipe eight inches in diameter, which soon divides into two branches; one runs into the top of a big cylinder, three feet across and very strongly built, contains a piston which, continually bathed in oil, fits it exactly like that of a pump. This is made of iron and is very heavy. It is this piston which the steam must drive up and down and then put the wheels in motion. To this end, the cylinder is pierced by four holes, two at the top and two at the bottom, and diametrically opposed. Each of these has a valve. Let us suppose the piston to be at the bottom, and that it is set in motion. The steam forces its way through the first valve, and the instant this opens inwardly, one of those at the top opens also, but

¹⁰⁶ S. Vail, “Accidents on Board of Steam Boats,” *HD* 18th Congress, 2nd session, 116 (1825): 14. In this letter to the Secretary of the Treasury about accidents on board steamboats, the Vesuvius was listed as having a low-pressure engine. In a letter by an “old timer” regarding steamboat engines from 1812 to 1826, the Vesuvius is mentioned as having a low-pressure condensing engine on the Bolton and Watt plan (Gould, *Fifty Years*, p. 167.)
outwardly, in order to allow the air to escape. The steam entering through the lower valve, causes the piston to rise, and in so doing meets with no resistance. When it reaches the top, the valve which hitherto had remained closed, opens, and the other top valve closes. The steam enters, drives the piston from the top to the bottom, then the valve in this part opens, allowing the first steam to escape. Arrived at the bottom of the cylinder, it goes up again, and thus is in motion.\textsuperscript{109}

There is no mention of a condenser in Montulé's description, despite the fact that Fulton built all of his steamboats on the low-pressure condensing engine plan pioneered by Bolton and Watt. Montulé goes on to speak of the dangerous pressure of steam in the boiler, and a safety valve which carried a weight of 16 pounds (7.3kg).\textsuperscript{110} This unusually high steam pressure, given the engine type, demonstrates the tendency of early western river engineers to disconnect the condensers, exhausting the steam directly into the air.\textsuperscript{111} The steam engine was worked in this manner for two reasons. First, the application of high-pressure steam imparted more power to the paddlewheel, giving the relatively weak power plant more force to counter the river currents. Second, suspended sediments in the rivers proved especially detrimental to the engines as they accumulated in the condenser.\textsuperscript{112} Montulé's description of the engine's operation without the condenser indicates a transitional step between the low-pressure condensing engine and the high-pressure engine.

\textsuperscript{109}Montulé, \textit{Travels in America 1816-1817}, pp. 102-03.
\textsuperscript{110}Ibid., p. 104.
\textsuperscript{111}Gould, \textit{Fifty Years}, p. 167
\textsuperscript{112}Walworth, \textit{The Wheeling Bridge Case}, p. 541.
Daniel French's second steamboat, the fourth on the western rivers, ran more successfully than his first. The 45 ton (40.8 metric tons) Enterprise had a length of 60 to 70 ft (18.3 to 21.3 m), a beam of 15 ft (4.6 m) and drew approximately 2½ ft (.8 m) of water. Following his patent, the engine was a 24 horsepower oscillating high-pressure engine. Steam was raised in two cylindrical boilers 25 ft (7.62 m) long, and 27 in (.7 m) in diameter, with at least one flue through each. Enterprise had several successful voyages under Captain Henry Shreve, and was credited as being the first steamboat to make the upriver journey from New Orleans to Louisville, and then on to Pittsburgh.

Washington, a 400 ton (364 metric tons) sternwheeler built by Henry Shreve in Brownsville, Pennsylvania, is typically viewed as the prototype of the later western river steamboats because of its engine type and layout. The diary of William Mercer, who traveled on the vessel in 1816, is the most complete, contemporary account of the vessel's structure and machinery.

The boiler is placed midships on the deck, and is heated by a furnace placed at either end. The steam is conveyed through two tubes to the machinery, which is under deck in the after part of the boat, and which, being set in motion, turns a single water wheel, placed near the stern, and concealed from the view of persons on the deck by a gentle elevation of the flooring timber. The arrangement below, is also, different. A common cabin about 80 feet long extends from the centre to either end. In the stern it opens into two apartments, one of which is a drawing room, and the other a dormitory, both appropriated, exclusively, to the use of the ladies. Towards the bow there are, also, two rooms, one of which is the private apartment of the captain and in the other, the

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113Maass, AN 56 no. 1 (1996): 36. Research sources about the dimensions of Enterprise are contradictory. Marestier states that "this boat, or one of the same name, is 24.38 meters (80ft) long, 9.14 meters (30ft) beam, 3.66 meters (12ft) depth of hull..." (Marestier, Memoir on Steamboats, p. 59). Marestier's dimensions seem too large for a vessel of 45 tons.

114G. Bathe and D. Bathe, Oliver Evans: A Chronicle of Early American Engineering, p. 217. This information was taken from a letter written by George Evans to his father, Oliver Evans, in 1814. It was his contention that Daniel French and several other steam engine manufactures were violating Oliver Evans' patent on high-pressure steamboat engines.

115Hall, Statistics of the West, p. 231.

116Marestier, Memoir on Steamboats, p. 59.
bar is kept. In the large, common room, there are 20 births, above & below, on either side of which is calculated for the accommodation of two lodgers.\textsuperscript{117}

Much of the historical evidence regarding this vessel is contradictory, although it does appear that Shreve was the first person to employ a horizontally oriented high-pressure engine.\textsuperscript{118} This attribute, as well as the placement of the boilers on the main deck, was adopted on nearly all later western river steamboats. The engine had a 6ft (1.83m) stroke and a cylinder with a diameter of 24in (.61m).\textsuperscript{119} It had a powerful 100 horsepower engine that weighed only 9,921 pounds (4500 kg).\textsuperscript{120} The loss of Washington and seven of its passengers when one of its boilers burst\textsuperscript{121} was the first of many explosions on the western rivers.

*General Pike* (Fig. 13), a sternwheeler built in 1818 at Cincinnati, was the first steamboat built exclusively for the conveyance of passengers. This vessel, powered by a high-pressure engine,\textsuperscript{122} was 100ft (30.5m) on the keel, had a breadth of 25ft (7.6m), and drew only 39in (1.0m) of water. *General Pike*’s cabin was 40ft (12.2m) in length, and was composed of 14 state rooms and a saloon which ran the cabin’s length. The vessel was equipped for the accommodation of 100 passengers.\textsuperscript{123}


\textsuperscript{118}Some sources credit Washington as the first vessel with a horizontal cylinder, to employ flues in the boiler, and to have a cam cut-off; see Morrison, *History of American Steam Navigation*, p. 207. Primary historic data indicates that Shreve did not invent either of these last two devices. Stephen Long claimed to have invented the cam cut-off (Walworth, *The Wheeling Bridge Case*, p. 550.) Oliver Evans’ description of an engine in 1792 describe a boiler with a flue (Bathe and Bathe, *Oliver Evans*, p. 34.)


\textsuperscript{120}Marestier, *Memoir on Steamboats*, p. 59.

\textsuperscript{121}Bathe and Bathe, *Oliver Evans*, p. 240.

\textsuperscript{122}C. Beverly, “List of Accidents from Bursting of Boilers, on Board of Steam Boats, upon the Mississippi, and its Tributaries,” *HD 18th Congress*, 2nd session 116 (1825): 15.

\textsuperscript{123}Gould, *Fifty Years*, p. 107; and Hall, *Statistics of the West*, p. 234.
*Maid of New Orleans* (Fig. 14) was built in 1818 at Philadelphia, and sailed from that port to New Orleans for use on the Mississippi River. This eastern-built steamboat had features atypical of later western river steamboats. Prominent in the depiction (see figure) were the walking beam engine, bowsprit, transom stern, and cabins below the main deck. The vessel was originally equipped with two masts and was rigged as a schooner, but the masts were removed sometime after its arrival in the West.

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Western Engineer was built at Pittsburgh in 1818 under the supervision of Major Stephen Long of the U.S. Topographical Engineers. The vessel was a sternwheeler with a length of 75ft (22.9m) and a breadth of 13ft (4.0m). Western Engineer was designed for an expedition up the shallow Missouri River, and consequently the hull drew only 30in (.76m) of water. The most unusual feature of this steamboat was the serpentine figurehead from whose mouth spent steam was vented, an apparent attempt to gain the respect of and/or instill fear in the Native Americans. The high-pressure engine of this steamboat had one improvement which was subsequently incorporated on all later western river steamboats. "By...use of the cut off cam...the steam is made to act with its full (or boiler) force through about five-eights of every stroke of the piston; and by its inherent or expansive force only, through the residue of the stroke, thus nearly doubling the efficiency of the steam power, in comparison with that previously employed in western river boats." The vessel was powered by three cylindrical boilers, 15ft (4.6m) long and 20in (.5m) in diameter. The boilers carried a working pressure of 96 pounds (43.6kg) per square inch (2.5cm), which was on occasion raised to 128 pounds (58.1kg).

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125 Gould, Fifty Years, p. 109.
127 Walworth, The Wheeling Bridge Case, p. 550. This information was taken from the testimony of an engineer, Stephen Long.
STRUCTURAL CHARACTERISTICS

The earliest steamboats on the western rivers bore little resemblance to the western river steamboat of the mid-nineteenth century. As stated earlier, steam technology at the time of its application to the western rivers was in an early form, necessitating a period of trial and error. During this time builders experimented with hull form, cabin arrangement, and paddlewheel structure and placement. Shipwrights and steam engine builders began the process of adapting their vessels and machinery to the western rivers, although the lack of an accepted way of building steamboats meant that there was no consensus on their ideal form.

In general, steamboats of this period were characterized by heavily built, deep-draft hulls with a marked sheer. Many of these vessels were quite small, since the earliest western river shipwrights treated the shallow draft problem by building smaller vessels, which naturally drew less water. This solution limited the vessel’s draft, but constrained cargo capacity. Hull form was more consistent with ocean-going vessels than of craft expected to travel on shallow rivers, although some modifications based on river conditions were implemented with surprising rapidity. Hulls were constructed with double frames and thick planking to protect against impacts with snags or drift wood. Additionally, many early steamboats were equipped with a snag chamber. This transversely oriented, watertight bulkhead was designed to prevent the entire hull from flooding when a snag punctured the bow. Many steamboats were still equipped with masts and rigging for harnessing the wind

130Hunter, Steamboats on the Western Rivers, p. 72.
when appropriate. Other features such as figureheads and bowsprits were also common during this period. All of these features would be discarded in the coming decades.

The deep hulls of early steamboats provided enough room in the hold to transport cargo and passengers. Passenger's quarters were commonly located below decks, although some steamboats did have a cabin that spanned the after section of the main deck. Either of these two types would often have a section of the uppermost deck covered by an awning, so that passengers could be outside, but protected from the elements.

**MECHANICAL CHARACTERISTICS**

The steamboat engines used on the western rivers during this period can be divided into two types: low-pressure condensing and high-pressure engines. Low-pressure condensing engines utilized steam of only a few pounds greater pressure than that of the atmosphere. The driving force upon the piston was achieved by creating a partial vacuum in the condenser, which was located below the cylinder. A spray of water in the condenser rapidly cooled the steam, thereby causing a reduction in steam volume. This partial vacuum was created either below or above the piston, depending on its position in the stroke. The piston was driven inside the cylinder by the low-pressure steam on one side and the partial vacuum on the other. In the early years of steam navigation, this type of engine was said to follow the Boulton and Watt plan, after its inventors James Watt and Matthew Boulton.

A high-pressure engine was worked by the steam pressure and the expansive power of steam. After being generated in a boiler sufficiently strong to withstand high pressures, the steam was introduced into the cylinder. The steam was injected into either the top or bottom of the cylinder, depending upon the location of the piston in its stroke. The tremendous pressure of the steam would then be forced to drive the piston. Often the supply of steam into
the cylinder would be cut off before the piston had moved the entire length of the cylinder. After being cut off, the steam would expand in the cylinder, pushing the piston for the remainder of the stroke. At the completion of the stroke the steam was exhausted from that side of the cylinder and injected into the other, thereby moving the piston in the opposite direction. The simplicity of this engine type made it considerably lighter and smaller than low-pressure engines.
V: DEVELOPMENTAL PHASE (1820 to 1835)

During the 1820s, steam navigation on the western rivers exited its early experimental period and began to have significant, positive impacts on the economic, industrial, and agricultural life of the trans-Appalachian West. Through trial and error by shipwrights and steam engineers the multiplicity of steamboat hull and engine types declined by the early 1830s, and a distinct vessel designed expressly for the western rivers emerged. Further modifications in machinery and hull lines proceeded through century's end, but these were refinements, not revolutions. Reflecting upon the first decades of the nineteenth century, James Hall stated in 1846 that steam navigation had been brought from “an unpromising beginning, through discouragement, failure, disappointment - through peril of life, vast expenditure of money, and ruinous loss, to the most complete and brilliant success”, furthermore, in this accomplishment “science pointed the way, but she did no more; it was the wealth of the Western merchant, and the skill of the Western mechanic, that wrought out the experiment to successful issue”. The “successful issue” of which Hall spoke was the increasing economic efficiency of the western river steamboat due to its physical evolution from a deep-draft ship to a shallow-draft inland craft.

In the 1820s there existed nowhere in the world an established tradition of building steamboats, let alone in the wilderness of the trans-Appalachian West. The nascence of steam technology compelled shipwrights to experiment with hull form and machinery type. Initially, steamboats were built in the East because of that region's industrial capability. Western rivers, however, demanded specific adaptations that could not, for a number of reasons, be

adequately addressed by shipwrights in the East. As such, the steamboats introduced from the East to the West were imperfect in form. Building upon the technological base supplied by eastern steamboat builders, western river shipwrights experimented widely to find the combination of characteristics that would overcome the challenges presented by the western rivers. Western urban centers saw more and more boatbuilders producing steamboats, but through the early 1820s steamboats intended for western rivers were built in both the East and the West. By mid-decade, however, only western shipwrights were producing steamboats for the western rivers, especially in the cities of Cincinnati, Louisville, and Pittsburgh.

Geography favored steamboats built in the West for a number of reasons. Western boatbuilders could observe the performance of their vessels; consequently, they were able to employ or discard design features based on their own empirical observations. Eastern boatbuilders were not witness to the results on the western rivers of these early, exported steamboat efforts, and so were not inspired to make appropriate changes. Another disadvantage to building steamboats in the East that were destined for the West was the oceanic voyage from the eastern shipyard to the West. This journey was not only costly and risky, but a ship designed to make such a journey would by nature not be practical on the western rivers. The deep-draft and heavy construction of these steamboats, so necessary for ocean conditions, were not at all conducive to traveling on shallow rivers. Lastly, the plentiful timber supplies of the West made ship construction inexpensive, and provided a fuel source so ample that efficiency was not a primary consideration in the development of steam machinery.¹³³

¹³³In 1880 Henry Hall estimated that the Marine Railway and Dry Dock Company in Cincinnati, Ohio wasted fully one half of the wood used in constructing steamboats (Hall, Report on the Ship-Building Industry, pp. 174, 190, and 243.)
During this period, western river steamboat design saw several adaptational developments. Most importantly, steamboat hulls became shallower and more flat-bottomed. As a consequence, passenger accommodation was moved entirely above the waterline. Structural improvements were paralleled and complemented by advancements in the design of engines and boilers. The light and powerful high-pressure steam engine was universally adopted on the western rivers by the late 1820s. Figures 15 through 17 are contemporary depictions of three steamboats from this era.

Fig. 15. Henry Shreve's George Washington built in 1825 (from the collection of Frederick Way, Jr. at the Inland Rivers Library)

Fig. 16. A painting by George Catlin of the steamboat Yellowstone built in 1831 (Axelrod, Art of the Golden West, p. 131)
STRUCTURAL CHARACTERISTICS

Statistics indicate that between 1818 and 1835 steamboat hulls for all tonnage groups became longer, beamier, and shallower. In the 100 to 125 tonnage class, average hull length increased by 16 percent and breadth increased by 6 percent, while depth decreased by 29 percent, with similar changes in the 200 to 225 and 400 to 500 tonnage classes. The rapidity with which these changes were implemented was due in part to the disposition of western river shipwrights. Neither nineteenth century theories of naval architecture nor theoretical deductions based on scientific experiments had any place in building western river steamboats. The evolution of this class of vessel was an incremental, yet swift, process by which western shipwrights built vessels according to their own observations and sensibilities, without the use of general principles. Universally adopted rules for steamboat building were nonexistent; the prevailing rule was that of trial and error. Accurate designs or drawings were rarely drafted (none of which have survived); weights and displacements were rarely

134 These figures are based on Table 4 in Hunter, Steamboats on the Western Rivers, p. 74.
calculated.\textsuperscript{136} As evidenced by the contract for the construction of the steamboat Yellowstone and later records from the Howard Ship Yard and Dock Company, individual vessels were built based upon the desired characteristics of the completed vessel, including the overall dimensions and the dimensions of key structural features. Often, such a textual description was clarified only by a quickly rendered sketch (Fig. 18).\textsuperscript{137}

![Diagram](image)

**Fig. 18.** Diagram detailing the cross-section of a steamboat to be built by the Howard Ship Yard and Dock Company in 1882 (Howard and Company Record Book, p. 96)

Western river steamboat development was strongly influenced by eastern shipwrights. Numerous shipwrights in the early nineteenth century migrated from the east coast to the western shipbuilding centers of Pittsburgh, Louisville, and Cincinnati.\textsuperscript{138} The ocean-going shipbuilding techniques these craftsmen brought with them may have initially slowed the evolution of the western river steamboat. As these shipwrights became familiar with the

\textsuperscript{136}Ward, TNAME 17 (1909): 79.

\textsuperscript{137}See D. Jackson, Voyages of the Steamboat Yellowstone, pp. 160-162; and J. Howard, Howard and Company Record Book.

\textsuperscript{138}Hunter, Steamboats on the Western Rivers, p. 68.
floors were spaced 17in (43.2cm) on centers, with the futtocks let into the floors 1in (2.5cm). The framing at the bow was more robust to resist damage from snags or driftwood. Double frames were ordered for the forwardmost 50ft (15.2m) of the hull, with the space between the frames reducing to only 2in (5.1cm) within 15ft (4.6m) of the stem. The bow was also equipped with a snag chamber "well fitted and caulked."\[140\]

**Superstructure**

The evolution of the steamboat's hull form directly affected the development of its superstructure. During the early 1820s, reduction of the depth of hold made that location an increasingly inconvenient space within which to house passengers. This diminished depth forced passenger accommodations to the main deck and above, with the hold being reserved for cargo. Henry Shreve was widely credited for being the first shipwright to build a vessel with an upper deck in his second vessel *George Washington* (1825) (see Fig. 15), although the *Emerald* of 1824 seems to have also had this feature.\[141\] Identifying the exact vessel or builder to first employ this design innovation is beside the point; more importantly, regional shipwrights were presented with the same set of problems and constraints and, not surprisingly, similar solutions were derived.\[142\]

By the mid-1820s passengers were commonly housed on both the main deck and the upper deck, more commonly known as the boiler deck. The *Reindeer*, which ran 1827-29, was described as having the gentlemen's cabin on the main deck, abaft the machinery, while the ladies' cabin occupied the after portion of the upper deck. The forward portion of the

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\[141\] Hunter, *Steamboats on the Western Rivers*, pp. 89-90.

\[142\] Ibid., p. 90.
upper deck was reserved for deck passengers. This arrangement quickly gave way to all of the cabin passengers being housed on the boiler deck, with the ladies cabin abaft the gentlemen’s cabin. Deck passengers were forced to find accommodations among the cargo and machinery on the main deck. Each cabin was partitioned with either a curtain or a door, with the cabins opening into a saloon, or long hallway that ran the length of the boiler deck. The saloon was used as the dining room, and was generally an area for interaction among the more privileged passengers. The outboard edge of the boiler deck was ringed by a gallery, an open walkway which served as an airy place of relaxation for the cabin passengers. On some steamboats, the passenger cabins opened onto the gallery, while others had small hallways leading from the saloon to the gallery.

The upper deck of the steamboat was often decorated in elaborate fashion with intricate paintwork, expensive carpets, chandeliers, sofas, tables, and chairs. This was in stark contrast to the utilitarian look of the main deck. The disparity between the two decks was not lost on contemporaries. Traveling aboard a western river steamboat in 1838, David Stevenson observed that the after end of the lower deck, “which is covered in, and occupied by the crew of the vessel and the deck passengers, generally presents a scene of filth and wretchedness that baffles all description.” By contrast the upper deck was “fitted up in a gorgeous style; the berths are large, and the numerous windows by which the cabin is surrounded give abundance of light, and, what is of great consequence in that scorching climate, admit a plentiful supply of fresh air.”

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143Walworth, The Wheeling Bridge Case, p. 80.
144Duden, Report on a Journey to the Western States of North America, p. 192; Gerstner, JFl 1, no. 2 (1841): 77.
145Stevenson, Sketch of the Civil Engineering of North America, p.152.
146Ibid., p.152-153.
MECHANICAL CHARACTERISTICS

Throughout the 1820s the diversity in steamboat boiler and engine designs declined, and machinery specifically designed for the swift, shallow western rivers and the region's plentiful fuel supplies became prominent. At the close of the decade, not only had the high-pressure engine become the dominant type used, but its positioning and design had developed into the general form it would retain for the remainder of the century. In pace with its evolution overall, the steamboat's steam machinery evolved with tremendous rapidity. Within 20 years the power plant was entirely revamped to suit the requirements of the western rivers.

Low-Pressure Steam Machinery

Western river steamboats powered by low-pressure engines during the 1820s were for the most part of eastern manufacture. Several drawings show low-pressure engines used on the western rivers during this period, the best being that of the Robert Fulton (Fig. 19), built in New York City in 1819 for use on the western rivers. Its journey from New York to New Orleans, which it completed in the spring of 1820, distinguishes it from later western river steamboats, for the lightly-built hull and superstructure of later boats would have certainly been destroyed by such an oceanic journey. Robert Fulton had a length of 158ft (48m), a beam of 33ft (10m) and depth of hull of 10ft (3m). Its single boiler (Fig. 20) was 30.8ft (9.4m) long, 8.9ft (3.9m) wide, and 8.9ft (2.7m) high, and while the working pressure of this large boiler is not known, it can be surmised from its box-like shape that it was low. The boiler, heated by a single furnace, had four horizontal flues that ran to the back of the furnace, returned over themselves, and united at the smokestack. French marine engineer Jean Baptiste Marestier,

147 Marestier, Memoir on Steamboats, pp. 8-9.
148 Ibid., p. 58.
149 Ibid., p. 34.
in his account of Robert Fulton, does not specify the material used to construct the boilers; given the vessel’s oceanic journey and the rapid corrosion of iron when exposed to salt water, however, it is likely that copper was used. Robert Fulton carried a low-pressure double acting side lever engine. The cylinder had a diameter of 3.7ft (1.13m) and a piston stroke of 5ft (1.52m).\textsuperscript{150}

\hspace{1cm} Fig. 19. Cross-section of the low-pressure condensing engine from the steamer Robert Fulton (from Marestier, Memoir on Steamboats, pl. V)

\textsuperscript{150}ibid., p. 58.
Fig. 20. Schematic drawings of the boiler of Robert Fulton (Marestier, Memoir on Steamboats, pl. IX)

High-Pressure Engines

By 1830, the basic design and layout of the high-pressure engine had been well established, but there were still no standards or specifications for the details of its construction. This lack of standardization, compounded by the absence of a steamboat building tradition, facilitated continual improvement by machinists of all aspects of the engine. The experimentation was implied by steamboat builder Reuben Miller in 1850 during his testimony in the Wheeling Bridge Case regarding the construction of boilers, when he revealed that there were no general rules in the construction of the furnace, the grate bars, the diameter of the
flues, or the diameter and length of the chimneys.\footnote{Walworth, *The Wheeling Bridge Case*, p. 89.} The infancy of steam technology allowed for experimentation that produced uniquely adapted machinery over the course of a few short decades.

Given the conditions of western rivers, the high-pressure engine and shallow-draft, flat-bottomed hull were necessary characteristics of steamboats, which had to not only draw minimal water, but stem rapids and occasionally deepen channels by ploughing through riverbeds.\footnote{Walworth, *The Wheeling Bridge Case*, p. 442. This information was taken from the testimony of Professor John Locke.} The high-pressure engine was approximately 60 percent lighter than a low-pressure condensing engine, decreasing the overall weight of the steamboat, and likewise, its draft.\footnote{N. S. Russel, "On American River Steamers," *TINA* 2 (1861): 123-124.} Additionally, the power supplied by the high-pressure engine was far superior to that of the low-pressure condensing engine. Though fuel consumption of this engine type was high, such a drawback was relatively minor in light of the West's plentiful and inexpensive fuel supply.

In 1860, Norman Russel, a British naval architect, noted that in comparison to a comparable, ordinary condensing engine, the high-pressure engine of a western river steamboat was 60 percent cheaper.\footnote{Ibid.} This was due largely to its simplicity of design and lack of ornamentation. Furthermore, since engineers were not formally educated in steam engineering, and there was a dearth of machine shops through much of the trans-Appalachian West, there was an added benefit to the uncomplicated high-pressure steam engine machinery: they were much easier to repair. Steamboats were often hundreds of miles from
a city with significant industrial capabilities, so the ability of western engineers to repair their own engines was essential.

Additionally, the straightforward nature of the high-pressure engine was better suited to the peculiarities of river navigation. In particular, the limber hulls of western river steamboats constantly altered the alignment of the machinery.\textsuperscript{155} The simple high-pressure engine, not built with anything approaching precision, was more easily adjusted to these frequent changes in alignment than a well-made and accurately fitted low-pressure engine. Finally, the silty nature of river water was believed to adversely affect low-pressure engines more than those of high-pressure. The sediment contained in the steam accumulated in the condenser, rendering it inefficient and causing continual "vexation and annoyance."\textsuperscript{156}

Testimony given by civil engineer Edwin F. Johnson during the Wheeling Bridge Case encapsulates the reasons and enthusiasm for the adoption of high-pressure engines during this period.\textsuperscript{157}

The conditions important to that navigation are lightness of draft of the boats, and a sufficient power in the engine to propel boats at the required speed. To this end it is essential that the engines with their appurtenances should have the least possible weight; this is attained by dispensing with the condensing apparatus and giving the cylindrical form to the boilers; so as to use, with greater safety, steam of a high pressure, in boilers of a small size and weight.\textsuperscript{158}


\textsuperscript{158}Walworth, \textit{The Wheeling Bridge Case}, p. 224.
The universal adoption of high-pressure steam machinery on western waters was rarely viewed in a favorable light by outside observers, however. Critics in both the eastern United States and England, where low-pressure steam engines were commonly employed, often called this technology dangerous and wasteful, especially when applied by ignorant, reckless western engineers. Writing the Journal of the Franklin Institute, J.V. Merrick expressed the dissenting opinion held by many:

The Western steamboats are made on a peculiar type, which is to be found principally in that section of the country, and whose existence at this stage of improvement in river navigation only serves to show how far prejudice, and a spirit of servile imitation, can prevent advances dictated by science, or by successful experience elsewhere.\textsuperscript{159}

The high-pressure engines used on western river steamboats were well-adapted to the surrounding conditions, but were much more dangerous and wasteful than low-pressure condensing engines.

Unfortunately, there are currently no known illustrations of high-pressure engines from western river steamboats dating to the 1820s; the earliest representation was published in 1840.\textsuperscript{160} In general, steamboats of this era were powered by one horizontally oriented poppet valve engine located on the main deck. The cylinder of the engine was 12 to 20in (.3 to .51m) in diameter, and the stroke of the piston was between 3 and 5ft (.91 and 1.52m).\textsuperscript{161} The exact manner in which this type of engine functioned will be discussed in more detail in the following section.

\textsuperscript{159} J.V. Merrick, "On the Steamboats of the Western Waters of the United States," JFI 23, no. 5 (1852): 344.

\textsuperscript{160} See P. R. Hodge, The Steam Engine Its Origin and Gradual Improvement, pls. 30-31.

\textsuperscript{161} J. Water, "Steam Engines," HD 25th Congress, 3rd session, 345 (1838):321-324. This information is based on statistics recorded for the construction of steamboats in Louisville, Kentucky between 1819 and 1838.
High-Pressure Boilers

Technical literature regarding the design and development of the machinery of western river steamboats is scarce, the notable exception to this being the documentation of high-pressure boilers. The tendency of boilers to explode, often taking many lives, placed them under public scrutiny again and again during the nineteenth century. The horrific loss of life and potential remedies for boiler explosions were investigated in numerous technical journals and by the Congress of the United States. A clear understanding of the power plant of the western river steamboat can be drawn from this information.

The cylindrical high-pressure boiler developed for western river steamboats during this period was a direct descendant of the type designed by Oliver Evans. Evans’ *Abortion of the Young Steam Engineer’s Guide*, published in 1805, describes boilers of the type used on western river steamboats. The boilers were oriented horizontally, and cylindrical in form with a diameter not exceeding 3ft (.91m). The amount of steam generated by these boilers was increased by either lengthening them to between 20 and 30ft (6.1 and 9.1m) or by increasing their number. Two different designs were proposed for exposing the boiler surface to the heat of the furnace. In the simpler and cheaper method, the furnace was set at one end of the boiler and the flame was allowed to travel the length of the boiler. The second design, which was adopted on the western rivers, was the use of an internal flue. Evans believed that although this latter design was expensive to construct, it would need only two-thirds as much fuel as the former type.\(^\text{162}\)

The boilers for steamboats on the western rivers were long and cylindrical, and positioned horizontally just forward of amidships on the main deck. They were constructed with little regard for efficiency, with minimum weight, bulk, and cost prevailing over all other qualities. They were revered by engineers on the western rivers for their ease of cleaning and repair, and reviled by many others for their frequent explosions. The number and dimension of boilers varied over time as steam engine builders experimented to find a design that combined minimum weight and cost with maximum strength and power. In the 1820s, two to three boilers with diameters of 18 in (46 cm) and lengths of 18 ft (5.5 m) were sufficient for powering a steamboat, but this soon increased. In 1831, steamboats typically had four or five boilers, each with lengths of 18 to 20 ft (5.5 and 6.1 m) and diameters of 3 ft (.91 m). In the mid-1830s, the use of eight boilers with diameters of 3.5 ft (1.1 m) and lengths of 23 ft (7.0 m) was not uncommon (Fig. 21).

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164 J. S. Williams, “Propositions and Suggestions on the Means of Obviating or Lessening the Accidents Incident to Navigation by Steam,” JFI 8, no. 4 (1831): 289
165 Water, HD 25th Congress, 3rd session, 345 (1838):321-324. This information was based on statistics recorded for the construction of steamboats in Louisville, Kentucky between 1819 and 1838.
from 1840 (after Hodge, The Steam Engine, pl. XXXII).
Fig. 21. Plan view and profile of the boilers of a western river steamboat fro
Boiler Shells. Boilers, with very few exceptions in the earliest years of this period, were constructed of iron.\textsuperscript{166} Through the 1820s boiler iron was wrought from solid slabs of iron worked together with a hammer.\textsuperscript{167} In the late 1820s, this process was altered so that iron plates were made with the use of large rollers. Blooms of iron were heated by anthracite coal and worked under a large hammer into thick slabs. Each slab was put under a roller, first in the direction of the slab's longitudinal axis and again perpendicular to its first orientation. The slab was thus reduced in thickness to a large bar, which was then cut to the desired length and width; several bars were piled on top of each other and then passed again, at a high heat, under a roller.\textsuperscript{168} The iron bars were not welded together as with forged iron, but soldered to each other by intervening layers of cast iron under the belief that this would reduce imperfections in the iron plate.\textsuperscript{169} The assumption was that multiple layers allowed for weak points in individual iron sheets to be strengthened by adjacent sheets.\textsuperscript{170} The boiler shell was assembled of these rolled iron plates joined by rivets. The individual boiler shells did not stand alone, but were joined to other boiler shells to create a battery of boilers. Each shell was connected to the adjacent shell by one or two large concave cast iron washers. The washers spanned the distance between each boiler shell, with their locations corresponding to a hole in each shell. This allowed the free flow of water within the battery of boilers. The boilers, once connected into a single unit, were held above the main deck by numerous wrought iron tie rods, which spanned the distance from the main deck to the base of the boilers.

\textsuperscript{166}Littlefield, Jfl 8, no. 5 (1831): 309.
\textsuperscript{167}C. Fox et al., Report on the Committee Appointed by the Citizens of Cincinnati, April 26, 1838, to Enquire Into the Causes of the Explosion of the Moselle, p. 24.
\textsuperscript{168}D. Embree, "Steamboats," HR 22\textsuperscript{nd} Congress, 1\textsuperscript{st} session, 228 (1832): 43.
\textsuperscript{169}Fox et al., Report on the Explosion of the Moselle, p. 24.
\textsuperscript{170}W. R. Johnson and B. Reeves, "Report of the Commissioner of Patents, to the Senate of the United States, on the Subject of Steam Boiler Explosions," SD 30\textsuperscript{th} Congress, 2\textsuperscript{nd} session, 18 (1848): 133.
**Boiler Heads.** Each end of the boiler was sealed by an iron boiler head. A boiler head was not a solid slab of metal, but was pierced by several holes. One hole went through the head for each flue in the boiler. The exception to this was in the case of elbow flues, described below. Each boiler head was equipped with a manhead, and often with a little manhead, as well. The manhead was an oval lid covering a hole in the boiler head. The manhead allowed a person to enter the boiler in order to clean the inside. The little manhead was a smaller hole with a corresponding lid located at the bottom of the boiler head. This allowed the water to be drained from the boiler, and for partial cleaning.\(^{171}\)

Cast iron heads were used throughout this period because of their ease of manufacture, but they were considered unsatisfactory in comparison to wrought iron heads. Cast iron heads were between 3/4 and 2 in (1.9 to 5.1 cm) thick, but air holes were often concealed in them during their manufacture, making them significantly weaker than they appeared.\(^{172}\) Furthermore, the repeated heating and cooling of cast iron damaged the metal, making cast iron heads prone to cracking.\(^{173}\) These cracks often proved to be weak points when a boiler was filled with high-pressure steam. Moreover, when the flue of a boiler collapsed, the shock from that process often broke the cast iron head through which the flue passed. Whereas a wrought iron head would tend to bend or tear, the cast iron head’s rigidity caused it to shatter. This resulted in fragments of the cast iron head being propelled with great force during an explosion. Calls were repeatedly made to eliminate the use of cast iron boiler heads.


\(^{173}\)Williams, *JFI 8*, no. 4 (1831): 289.
heads on western river steamboats throughout this period, but it was not until the late 1840s that their use was entirely phased out.  

Flues. The use of flues was readily adopted on the western rivers. Flues were iron tubes running the length of the boiler’s interior. These were open to the furnace, permitting hot gases to travel through them, thus providing a larger amount of surface by which to heat the water in the boilers. During the 1820s and 1830s, single flue boilers were 34 to 38 in (.86 and .97 m) in diameter with a 16 to 20 in (.43 and .51 m) diameter flue. Double flue boilers were 36 to 40 in (.91 to 1.02 m) in diameter, with flues of 12 to 17 in (.18 to .43 m) in diameter. Both types of boilers were 16 to 22 ft (4.9 to 6.7 m) in length.  

Through the late 1820s boilers were equipped with one flue, but preference was soon given to two flues. Not only were the sizes of these single and double flues different, but their constructions were also dissimilar. Single flues did not exit the boiler through the boiler head as did double flues. Single flues were known as elbow or L flues because in the forward part of the boiler they made a 90 degree turn upward, thereby exiting through the top of the boiler. This feature was believed to be the cause of several boiler explosions. The elbow portion of this type of flue was not covered by water as was the rest of the length of the flue. This prevented the exposed portion from being cooled by the water, and it thereby became


175Walworth, The Wheeling Bridge Case, pp. 399, 413, and 419.

176Ibid., p. 80.

red-hot and frequently lost its ability to withstand the steam pressure. In these instances the flue would collapse, often with catastrophic results. 178

Although elbow flues were especially prone to collapsing, all flues introduced an element of weakness into the boiler. A flue ran through the center of the boiler, and thus was exposed if the water level in the boiler dropped too low; without the cooling effect of the water, the flue became red hot. Two unpleasant outcomes often resulted from this situation. Either the heat from the furnace would cause the flue to become malleable and collapse, thus exploding the boiler; or the low water level would be discovered and water added to remedy the deficiency. This second action resulted in a dramatic increase in steam pressure from the instantaneous vaporization of the water when it hit the red hot flue. Sometimes the boilers would hold, and sometimes they would not.

Regardless of flue type, the juncture between the flue and the boiler or the boiler head was secured in the same manner. The end of the flue had a flange or washer around its end. These flanges were punctuated with rivet holes corresponding with holes in the boiler or the boiler head. The juncture of these two pieces of metal was made steam-tight with lead grummetts or collars sandwiched between the two pieces of riveted iron. 179

Safety Devices. Throughout the development of the western river steamboat, boilers were equipped with two basic safety devices: gauge cocks and safety valves. Gauge cocks (Fig. 22) were three small valves located one above the other on the boiler head. They were positioned just below, equal to, and above the desired water level. The valves were opened

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178 Burke, SD 30th Congress, 2nd Session, 529 (1848): 11; Walworth, The Wheeling Bridge Case, p.419.
180 Gauge cocks were also known as try cocks.
with a gauge stick (a broom handle): if water flowed when the highest gauge was opened, the water supply was cut off; if water flowed from the middle, but not the upper gauge, a normal supply of water was in the boiler; if only the lower gauge exhausted water, then more water was added. If all of the gauge cocks were dry "there followed a guessing match as to just how far below the minimum the water really was, and what would be the result of throwing in a supply of cold water. The supply was always thrown in, and that quickly, as time counts in such cases." Gauge cocks were widely acknowledged to be an imprecise indicator of a boiler's water level. The release of steam pressure by the opening of the gauge cock often caused the water in the boiler to foam, giving a false impression of the true height of the water.

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Fig. 22. Profile of a boiler head showing the gauge cocks (Bates, *The Western Rivers Engineerroom Cyclopaedium*, p. 17)

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Even from the earliest period, western river steamboats were equipped with one or sometimes two safety valves (Fig. 23). Safety valves were relatively small; in 1831 only half of them were more than one half the size of the engine's throttle valve, and no more than a third of the steamboats were equipped with more than one.\textsuperscript{183} They were the subject of much controversy, as they tended only to create a false sense of security. Simply constructed, a safety valve consisted of a lever with an adjustable weight which in theory allowed the amount of steam pressure held inside the boiler to be adjusted. When enough steam built up in the boiler to open the safety valve(s), the opening, generally only 3 to 5 in (7.6 to 12.7 cm) in diameter,\textsuperscript{184} could often not expel a volume of steam sufficient to avoid an explosion. In fact, the sudden release of steam pressure would bring about a rapid expansion of steam in the boiler, frequently more expansion than the valve could vent, resulting in an explosion actually caused by the safety valve.\textsuperscript{185} Most observers believed that the safety valve had "no more tendency to prevent an explosion than the touch hole of a cannon has to prevent it from bursting."\textsuperscript{186}

\textsuperscript{183}Benton, JFI 8, no. 5 (1831): 313-314.
\textsuperscript{184}Halderman, JFI 9, no. 1 (1832): 30.
\textsuperscript{185}J. Perkins, "Remarks on the Explosion of Steam Boilers," JFI 9, no. 5 (1832): 346.
\textsuperscript{186}Cist et al., SD 26th Congress, 2nd session, 378 (1841): 178.
Fig. 23. Cross-section of a safety valve (Russel, TINA 2 (1861): 124)

Adding to the dangers of this design flaw was the often reckless weighting of the safety valve. The amount of steam pressure carried in the boiler, which was left entirely to the discretion of the engineer, was an issue of much controversy. Safety valves were held down by a moveable weight, called the pea, on a lever known as the death hook.\textsuperscript{187} The death hook was so named because of the habit of some engineers to weight it excessively in order to increase boiler pressure, thereby supplying the engine with more power. This was said to be a very common practice, with engineers frequently placing "twice as much weight [on the death hook] as the steam can raise when the boat is under way."\textsuperscript{188} This practice was frowned upon, especially in light of the fact that engineers were rarely educated in their trade, and

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\textsuperscript{187} Bates, The Western Rivers Engineeroom Cyclopaedium, p. 18.
\textsuperscript{188} E. Jones et al., "Letter from the Secretary of the Treasury Transmitting Information Collected by the Department, Upon the Subject of Accidents on Board of Steam Boats," HD 18\textsuperscript{th} Congress, 2\textsuperscript{nd} session, 116 (1825):16.
\end{flushleft}
scarcely one in twenty could actually calculate the amount of weight on the death hook, relative to the pressure it withheld in the boiler. Repeated protestations were made by observers from the 1820s through the 1840s demanding that at least one safety valve be locked in such a way that the engineer could not access it, or to impose heavy fines for over-weighting it.

Steam pressure gauges, despite their apparent necessity, were not common on western river steamboats. Open tube mercury gauges had long been available for low-pressure boilers, but the excessive height of the column of mercury required to measure the steam pressure in a high-pressure boiler prevented widespread use of these gauges in the West. The invention of the Bourdon bent tube gauge in 1845 provided an adequate pressure gauge, but western river engineers were slow to adopt these expensive, complicated new technologies. In 1852, Samuel Gilman noted that only a minority of steamboats carried steam gauges, the actual working pressure of most boilers being mere conjecture.

Feed Water Pump. Essential to the operation of the steam plant was a means of filling the boilers with water. This was accomplished with a feed water pump that took its motion from the engine. The feed pump worked well, as long as the engine was in motion; however, when the engine was no longer in motion the feed water pump stopped supplying water to the boilers. For short stops this was often not a problem, but if the engines were halted for any length of time the water level in the boilers could become dangerously low.

189 Haldeman, JFI 9, no. 1 (1832): 30; and Walworth, The Wheeling Bridge Case, p. 72.
191 Hunter, Steamboats on the Western Rivers, p. 163.
192 Gilman, JFI 24, no. 3 (1852): 210.
193 Burke, SD 30th Congress, 2nd session, 529 (1848): 20.
This problem was overcome by throwing the paddlewheels out of gear so that the engines could continue to work, without propelling the vessel. This was a wasteful and inconvenient technique, and frequently the fire in the furnace was not dampened during stops and the steam from the boilers was merely allowed to vent through the engine cylinders. In this practice the water supply in the boilers was rapidly depleted, potentially exposing the flues to the heated gases from the furnace without the cooling effect of the water in the boiler. When the engine was again set in motion, water would be forced into the boilers. The cold water on the red-hot flues would instantly vaporize, causing an abrupt rise in steam pressure, all too frequently causing an explosion.

Drums. Boilers were connected to each other by several drums, both above and below the boilers. Located above and perpendicular to the battery of boilers, the steam drum served to collect the steam prior to it being used to power the engine. It was cylindrical and constructed of plate iron similar to the boiler shell. The mud drum was of similar construction and orientation, but was located below the boiler. This device was first used on the western rivers in the late 1820s and was subsequently incorporated into the machinery of all western river steamboats. The iron cylinder made the cleaning of the boilers less frequent, since sediment accumulated in the mud drum, and could be removed via a blow-off valve several times a day.

194 Stevenson, Sketch of the Civil Engineering of North America, p. 157.
196 Benton, JFI 8, no. 5 (1831): 314.
**Furnace.** The fire was generated in the furnace at the forward end of the boilers. The position of the furnace, combined with the longitudinally oriented boilers, created a strong natural draft.\(^{199}\) Access to the furnace was through the furnace doors, located in between each pair of boilers. The grate, upon which fuel was placed, averaged 4ft (1.2m) in depth,\(^{199}\) and spanned the combined width of all the boilers. Openings between each grate bar varied from 5/8in (1.6cm) for coal, to 1in (2.5cm) for wood.\(^{200}\)

**Casings.** A casing of sheet iron encompassed all of the furnace and the bottom half of the boilers. This feature was designed to keep the heat from the furnace in contact with the boilers, and to force the furnace gases through the flues and into the chimneys. The casing was typically 3/16in (.48cm) thick, although frequently thicker at the after end, or back wall, and at the forward end, or breeching.\(^{201}\) The breeching was the intermediate stage between the casing and the chimneys. The breeching collected the gases from the numerous flues and transferred them to one of the two chimneys. The breeching was equipped with doors to allow access to the boiler heads, so that the boilers could be cleaned.\(^{202}\)

The tops of the boilers were not covered by the casing, but were generally insulated by some means. Contemporary accounts describe mixtures of plaster or clay, but Bates notes

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\(^{199}\)Stevenson, *Sketch of the Civil Engineering of North America*, p. 152. This positioning also served to announce the approach of the vessel at night.

\(^{199}\)Walworth, *The Wheeling Bridge Case*, pp. 635-39. This information is based on a table of measurements of steamboats compiled by Israel Dickenson.

\(^{200}\)Ibid., p. 89.

\(^{201}\)Stevenson, *Sketch of the Civil Engineering of North America*, p. 156. The breeching was also commonly referred to as britching.

\(^{202}\)International Correspondence Schools, *The Machinery of Western River Steamboats*, p. 60.
that many other materials such as asbestos, firebrick, fireclay, and combinations of manure, straw and earth were also applied.\footnote{Bates, \textit{The Western Rivers Engineer's Cyclopoedia}, p. 11; Stevenson, \textit{Sketch of the Civil Engineering of North America}, p. 156; and Walworth, \textit{The Wheeling Bridge Case}, p. 452.}

**Fire Bed.** The boilers, although located on the main deck, did not rest on the deck itself. A single layer of brick, laid flat, was placed on the deck to insulate it from the heat of the furnace. The edge of the fire bed would be made more pronounced by laying the end bricks on their sides.\footnote{Walworth, \textit{The Wheeling Bridge Case}, p. 572.}

**Boiler Maintenance.** The boilers of western river steamboats, although exempt from the corrosion problems caused by salt water, were subject to the drawbacks of using the silty water of the Mississippi Basin. Sediment and plant debris accumulated quickly, and needed to be removed. This was partially accomplished by opening the valves of the mud drum, allowing accumulated sediment to blow out. Although this cleared much of the sediment from the bottoms of the boilers, it did not entirely clean them. Not all of the sediment would accumulate in the mud drum; the remainder formed a dense deposit in the bottom of the boiler. This deposit, often described as being brick-like in density, tended to reduce the heat transfer from the furnace to the water. Another drawback to using river water was the dissolved minerals and salts it contained. These compounds had the potential to form a crust on the boiler and flues, to the effect of sealing them off from contact with the water.\footnote{Cist et al., SD 26th Congress, 2nd session, 378 (1841):69; and Walworth, \textit{The Wheeling Bridge Case}, p. xxvii.} Lacking contact with water, the iron could become red hot and rupture.

Whether from accumulated sediment or mineral deposits, boilers required frequent cleaning to stay in peak working order. This unpleasant job was conducted several times per
journey, and normally by a cub-engineer. The experience of George Merrick as a cub-engineer accurately characterizes this task.

Being a slim lad, one of my duties was to creep into the boilers through the manhole, which was just large enough to let me through; and with a hammer and a sharp-linked chain I must “scale” the boilers by pounding on the two large flues and the sides with the hammer, and saving the chain around the flues until all the accumulated mud and sediment was loosened. Scaling boilers was what decided me not to persevere in the engineering line. To lie flat on one’s stomach on the tip of a twelve-inch flue, studded with rivet heads, with a space of only fifteen inches above one’s head, and in this position haul a chain back and forth without any leverage whatever, simply by the muscles of the arm, with the thermometer 90° in the shade, was a practice well calculated to disillusionize any one not wholly given over to mechanics.206

Paddlewheels

Throughout the nineteenth century, paddlewheels were the exclusive method used to propel western river steamboats. Paddlewheels had several advantages over the obvious alternative, the screw propeller. Most significantly, working propellers were not available until circa 1840, long after the hull form and machinery of western river steamboats were well-established. Even after the successful application of propeller technology on the Great Lakes and elsewhere the use of this machinery on western rivers still presented nearly insurmountable problems. Early propeller shafts were prone to leakage, with the river sediment damaging their watertight seals. These joints and seals were difficult to repair, especially given the lack of facilities for drydocking vessels.207 Moreover, the propellers on large vessels required a considerable depth of water, often not available of western rivers. In these shallow waters propellers were vulnerable to snags, and once damaged their repair required specialized machinery not found in ordinary machine shops.

206 Merrick, Old Times on the Upper Mississippi, p. 37.
In contrast, paddlewheels as developed on the western rivers were consistent with other trends seen in the construction of this type of steamboat. Paddlewheels were relatively uncomplicated and inexpensive devices that could be maintained without access to machine shops or iron foundries. The simplicity of the paddlewheel made it easy to repair, an essential feature given that paddlewheels were commonly damaged by floating debris, and steamboats were often hundreds of miles from urban centers. All of the paddlewheel’s parts were above the level of the water for all or most of its revolution. This eliminated the problems associated with watertight seals, and made repairs much easier to conduct because the paddlewheel needed merely to be stopped in order for a repair to happen. Paddlewheels, did, however, have significant drawbacks. In comparison to propellers, they were massively heavy, an unfortunate detraction given that shipwrights were continually trying to decrease the draft of their vessels. Paddlewheels were also quite inefficient, with the shower of water they lifted out of the river representing wasted fuel and money.\[206\] Neither of these detractions, however, was significant enough to outweigh the advantages of the paddlewheel.

Positioning the paddlewheels at the sides of the steamboat was preferred during this period. In the 1820s paddlewheels were frequently located amidships or slightly forward of this point; as time progressed the trend was to move the paddlewheels further aft. By the mid to late 1830s, the paddlewheels had been moved to one quarter or one third the length of the vessel forward of the transom. For sidewheelers, this position would be maintained for the remainder of the nineteenth century.

Throughout the Developmental Period, paddlewheels were increased in width and diameter. By increasing the paddlewheel’s diameter, the rotary speed of the wheel was

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increased without a corresponding increase in energy needed from the engines. As the diameter of the wheel increased, the height of the cylinder timbers upon which the paddlewheel shaft rested was raised. Increasingly, the cylinder was angled upward so that the pitman could rotate the paddlewheel shaft. Further details regarding the actual construction and structure of paddlewheels will be presented in the following chapter.

Chimneys

One of the most prominent features of western river steamboats was the pair of large chimneys located about one quarter to one third of the vessel’s length aft of the stem. The chimneys rose from the forward end of the boilers and were connected to them via the breeching. Well-made chimneys were essential to the proper firing of the boiler, and therefore the power of the engine. Chimneys carried the smoke and soot away from the vessel, but in this process they created a natural draft in the furnace. As the heated gases from the furnace rose inside the confined space of the chimney, they forced a flow of air into the furnace to fill the drop in pressure. This flow of air, the draft, forced oxygen into the furnace, accelerating the combustion of fuel. A secondary consideration in the construction of the chimneys was aesthetics. Although certainly not the primary feature, tall chimneys were seen as improving the looks of a vessel, and certain observers asserted that this was the sole reason for the towering chimneys of later western river steamboats.209

As with many features of the western river steamboat, chimneys grew in both their diameter and height throughout this and the next period. In 1850, a veteran steamboat commander estimated that in 1820 the average chimney was approximately 14ft (4.3m) high

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from the center of the flues with a diameter of about 12in (.3m).\textsuperscript{210} By the end of this period chimneys typically rose 25 to 45ft (7.6 to 13.7m) from the flues and were 25 to 40in (.64 to 1.0m) in diameter.\textsuperscript{211} One limiting factor regarding the height of chimneys was the tendency for taller chimneys to cause vessels to roll.\textsuperscript{212} As the average breadth of steamboat hulls increased through the 1840s and 50s the rolling problem would be largely annulled.

Chimneys were built of multiple sections of sheet iron riveted to each other. Each section of iron plate was know as a ring. Unlike the steamboats of the later nineteenth century, the tops of chimneys in this period were not typically decorated. However, the tops of some vessels of this era were equipped with "a semi circular sieve, in the form of a ball"\textsuperscript{213} intended to extinguish sparks as they exited the chimney. The use of this type of device was discontinued because it diminished the draft of the furnace.

\textsuperscript{210}ibid., pp. 407-408.
\textsuperscript{211}ibid., p. 419.
\textsuperscript{212}ibid., p. 389.
\textsuperscript{213}ibid., p. 633.
VI: MATURE PHASE (1835 to 1860)

During the early years of this period the structural and mechanical development of the western river steamboat was essentially completed. The earlier river steamboats had been deep-drafted, heavily built ships, but by this time they were transformed into shallow, lightly constructed, flat-bottomed vessels with multiple decks rising high above the waterline, a form retained for the remainder of the century. The steamboat's evolution from its earliest years through this period was not the result of great advances in technology or leaps of creative genius, but of incremental improvements in hull form and machinery by countless shipwrights, engineers, and mechanics. These advances were reflected in the western river steamboat's ability to carry more freight and passengers on less water than any other class of steamboat in the world. Moreover, the cost of steamboat construction per ton of freight, capacity, and passenger accommodation was less than any other type of steamboat.

Figures 24 through 26 show several views of Buckeye State (1850), a typical western river steamboat of this era. Buckeye State was a sidewheeler whose hull was built in Shousetown, Pennsylvania, and sent to Pittsburgh for the installation of her machinery and finishing of the superstructure. The vessel had a length of 260ft (79.3m), a beam of 29ft 5in (9.0m), and a depth of 6½ft (2.0m). The following drawings represent the earliest detailed technical drawings of a western river steamboat known to exist.

214Bryan, TASME 17 (1896): 393.
215Howe, Memoirs of the Most Eminent American Mechanics, p. 417; and Hunter, Steamboats on the Western Rivers, p. 121.
Fig. 24. Profile of Buckeye State (Tredgold, The Principles and Practice and Explanation of the Machinery Used)
Fig. 25. Bow view of Buckeye State (Tredgold, Machinery Used in Steam Navigation, Volume II, Part II, pl. 2)
Fig. 26. Stern view of Buckeye State (Tredgold, Machinery Used in Steam Navigation, Volume II, Part II, pl. 2)
STRUCTURAL CHARACTERISTICS

Sidewheeler v. Sternwheeler

This study focuses on the sidewheel steamboat and not the sternwheel steamboat because before the Civil War, sidewheelers were the dominant type. The development of the sternwheeler is an important topic, one that befits a study similar in nature to this one; however, most of the significant advances in sternwheel steamboat construction occurred after the period of this analysis. Therefore, the following few paragraphs present an outline of the basic development of the sternwheel steamboat within the temporal limits of this study, but by no means are they an exhaustive analysis.

Mounting the paddlewheel at the stern was quite common during the first fifteen years of steam navigation on the western rivers, but these sternwheelers bore little resemblance to those developed in the Mature Phase of steamboat development. Early sternwheelers had relatively small wheels set within the lines of the hull. This positioning restrained the size of the paddlewheel and took up a large amount of space in the hull. Furthermore, the weight of the paddlewheel at the stern made the hull prone to hogging. These early sternwheelers were superceded by sidewheelers in the 1820s. It was not until the 1840s that sternwheelers again became an unexceptional sight on the western rivers. In the following decades their numbers steadily increased until they effectively replaced sidewheelers in the post-bellum period.

Placing a single paddlewheel at the vessel's stern had two major advantages over positioning one on each side of the hull. First, the shape of a steamboat's hull tended to push any flotsam it encountered to the side of the hull. Thus, on sidewheelers, the debris would be forced straight into the paddlewheel. In contrast, a paddlewheel at the stern was mostly
sheltered from debris floating in the river; driftwood damage to the paddlewheel was thereby largely eliminated, leading to fewer stops during a journey. The second and most material advantage of placing the paddlewheel at the stern was the lower draft of sternwheelers compared with sidewheelers of equal tonnage. When paddlewheels were mounted at the sides, the overall breadth of the main deck was increased by the width of the paddlewheels via the guards. The guards were decking supported by outrigger beams which projected outside the lines of the hull. Sidewheelers during this period typically had guards with widths that were 50 to 75 percent of the breadth of the hull. Although the guards were used for cargo space on the main deck, their overall width was determined by the width of paddlewheels. Thus, the buoyancy of the hull was constrained by the necessity of always having to extend the breadth of the main deck by a width equal to that of the paddlewheels. Sternwheelers, on the other hand, generally had small guards or no guards at all. The length-to-breadth ratio for sternwheelers was generally less than that of sidewheelers, with a corresponding increase in the buoyancy of the hull for a given length. This was particularly important for western river steamboats because the length of a vessel's navigation season was dependent on the amount of water its hull drew. Sternwheelers, which could run on less water, could service a greater area for more of the year. This advantage became paramount in the post-bellum years with increasing competition from the railroads.

The major structural disadvantage of sternwheelers was hull distortion caused by placing the paddlewheel so far aft. This tremendous weight compounded the tendency for steamboat sterns to hog, an insurmountable problem before the successful employment of hogging chains in the late 1830s or early 1840s. It is no coincidence that sternwheelers came into favor shortly after this technological advance. Sidewheelers were braced by one
longitudinal hogging chain, while the predisposition for sternwheel steamboat hulls to distort required the use of two sets of longitudinal hogging chains, and two further sets of chains were used just to support the paddlewheel.

**Hull Shape**

Through experimentation, western shipwrights learned that steamboats equipped with long, narrow, flat-bottomed hulls were better able to combat the rapid currents and shallow waters of the western rivers. This type of hull displaced the largest amount of water possible, allowing steamboats to “keep as nearly as possible upon the surface of the water,” thus enabling vessels to more easily counter swift river currents. Longer vessels were also faster than shorter boats of similar tonnage because the extra length caused little additional resistance in the water, relative to a comparable gain in cargo capacity. Furthermore, the long, full hull form increased the vessel’s buoyancy, thereby allowing it to travel on less water. This permitted vessels to sail in shallower waters, and consequently increased their profitability, since the length of a steamboat’s running season was inversely proportional to its draft. Figure 27 presents the lines of *Buckeye State*, illustrating the long, shallow, flat hull shape.

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28Ibid., pp. 406 and 184.
29Ibid., p. 441
Fig. 27. Sheer, half-breadth, and body plan of Buckeye State (Tredgold, Machinery Used in Steam Navigation, V
The construction of the bow, much like the construction of the rest of the steamboat, was determined by river conditions. Widely varying river levels created impediments to the loading and unloading of passengers and freight. Seasonal fluctuations rendered permanent docks impractical because the docks would intermittently be either completely inundated by or too far above the level of the river. Many river landings and towns employed wharf boats or floating docks moored to posts, which allowed them to rise and fall with the river level.\textsuperscript{220} The more isolated and less frequently used river landings, however, found this too costly. Instead, the bow of the steamboat was designed with a long, rounded rake to accommodate the steamboat being eased up onto muddy riverbanks. Once the bow had ridden up onto the bank, a plank was quickly put out to the shore, and the steamboat was secured to a nearby tree.\textsuperscript{221}

Although the rake of a steamboat bow tended to be long and rounded, its overall form was subject to some variation. Jack Custer identifies three varieties: the model bow, the scow bow, and the spoonbill bow.\textsuperscript{222} The model bow was the standard form used during this period (see Figs. 24 and 27). It was generally employed on packets, the owners of which made much of their livelihood carrying passengers. Speed was important in this trade; therefore the model bow was designed to cut easily through the water. The scow bow was employed to some extent during this period; a bow of this type was documented on Cremona (1852). In this form the entire flat bottom of the vessel's hull raked up at the bow. This bow form was inexpensive and easy to build and repair, and it aided in lowering the draft of the vessel by

\textsuperscript{220}Hall, \textit{Report on the Ship-Building Industry}, p. 175.
\textsuperscript{221}Ibid., p. 176; and Tredgold, \textit{Machinery Used in Steam Navigation, Volume II, Part I}, p. 38.
increasing the surface area of the bow below the water. Scow bows were employed more extensively in the late nineteenth and early twentieth centuries. The spoonbill bow was used by many freight boats or low water boats, although this form did not become widespread until around 1870. The spoonbill shape placed more of the bow in the water, thereby reducing the draft of the steamboat and making its full form easier to pull off the riverbank.

Generally, a steamboat bow was more heavily built than any other part of the hull. One or more breast hooks were used to stiffen the bow against both landing on river banks and encountering driftwood or ice while traveling. Furthermore, the frames at the bow had less room and space and larger dimensions than those in any other portion of the hull. Even this staunch framing, however, did little to stop snags from puncturing the hull. Interestingly, the building of snag chambers in steamboat bows seems to have ceased during the early years of this period, despite the continued significant threat from snags.

The sterns of sidewheelers differed in nearly every aspect of their construction from those of sternwheelers. On sidewheelers the most complex portion of the hull to build was the stern. Starting from about the beginning of the aft quarter of the vessel, the hull form was altered from its rectangular shape to a much narrower form with the frames having considerable deadrise. In addition to having steep deadrise, the frames also arched outward, creating a hollow in the lines of the hull (Fig. 28). The fine lines of the stern served to minimized turbulence around the single, large, rectangular rudder, giving the vessel more maneuverability. The after end of the stern was marked by a counter stern within which the

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223 Custer, E$J$ 9 (1992): 27
224 B. Baldwin, “Pitsburg (sic) and Cincinnati Packet Line Stern Wheel Steamer Queen City,” ME 1 (1897): 6.
sternpost and rudder post were contained. The transom normally had the vessel's name painted on it.

In contrast to the sharp lines of sidewheeler sterns, those of sternwheelers were full, and generally much simpler to construct. The stern was built by raking the full, flat shape of the bottom of the hull upward just before it reached the transom. This increased the buoyancy of the stern, an important feature given the immense weight of the paddlewheel at the stern. The transom spanned most of the breadth of the hull, and was oriented vertically. In later decades the sterns of sternwheelers became more complicated with the addition of complex steering systems and hull shapes, but during this period they remained relatively uncomplicated.

Fig. 28. Photograph of the stern of the sidewheeler Liberty (1900) while under construction (courtesy of the Inland Rivers Library)
Superstructure

The superstructures of steamboats during this period were standardized to contain four decks: the main, boiler, hurricane, and Texas (Fig. 29). These multiple decks, stacked upon each other, gave the western river steamboat its distinctive wedding cake-like appearance. Western river steamboats looked distinctly top-heavy; between three-fourths and four-fifths of their total structural area was actually above the waterline. The apparent top-heaviness was lessened, however, by the placement of the machinery and cargo on the main deck, or, in the case of cargo, in the hold as well.225 All of the decks shared a number of features. Each had a slight camber; this modest rise toward the center of the deck helped to drain water and improved the looks of the vessel. The camber of the main deck also increased space in the hold, an important feature for shallow-drafted vessels. All of the decks had also a modest sheer both fore and aft. The sheer ranged from 4 to 5ft (1.2 to 1.5m) on large cotton packets, to 1ft (.3m) or less on low-water boats.

The main deck was the largest and most open of the decks. The upper half of figure 30 shows the layout of the main deck of Buckeye State. The main deck housed all of the machinery, heads, a blacksmith’s shop, bunks for deck passengers, and hatchways to the hold. The main deck was the primary storage area for the steamboat’s cargo, and was an area to which deck passengers were limited.

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225 Hunter, Steamboats on the Western Rivers, p. 91.
Fig. 29. Mid-ships cross-section of Buckeye State showing the main, boiler, and hurricane decks (Tredgold, Machinery Used in Steam Navigation, Volume II, Part II, pl. 4)
Fig. 30. Plan view of Buckeye State showing the layout of the main deck in the upper half and boiler deck.
the lower half (Tredgold, Machinery Used in Steam Navigation, Volume II, Part II, pl. 3)
The boiler deck, which had a width equal to the main deck, was used for the accommodation of cabin passengers. The lower half of figure 30 illustrates the layout of Buckeye State's (1850) boiler deck. The bulk of the deck was composed of individual cabins for passengers and a saloon, or a long central hallway, which extended the length of the deck. The boiler deck also contained the pantry, men's and women's heads, the bar, and a baggage room. The entire exterior of the deck was ringed with a walkway, allowing access to fresh air without descending to the main deck.

The hurricane deck formed the roof of the boiler deck, and was primarily open. The open portion contained skylights, which illuminated the saloon below. The forward portion of the hurricane deck had a series of cabins which accommodated the crew, and occasionally passengers as well. This series of cabins, known as the Texas, was instituted in the early 1840s. The Texas was originally an odd boxlike attachment to the hurricane deck, but in the following decades it was gradually lengthened until it spanned approximately one third the length of the vessel. Atop the Texas was the pilothouse. This cubelike structure was ringed with windows, and gave the pilots a commanding view of their surroundings.

226 Hunter, Steamboats on the Western Rivers, p. 90.
Hogging Chains

The design of the western river steamboat hull was both its greatest asset and its most significant drawback. As previously discussed, the steamboat hull was very shallow, long and lightly built. Sweeney asserts that steamboat hulls were "constructed with all the lightness in any way consistent with safety against falling to pieces."227 Not surprisingly, this hull structure had problems with hogging and sagging. Hull deformations had the potential to increase a steamboat's draft, throwing the machinery out of alignment, and twisting and rupturing steam and water lines.228 The limberness of the hull, however, was also an asset. Steamboat hulls needed to be flexible enough to avoid permanent damage from temporary deformations such as groundings and sinkings, and impacts with submerged objects. Engineers lessened the tendency for steamboat hulls to distort, while maintaining their limberness, through several means. First, the position of the machinery (on sidewheelers) placed all of the weight from the boilers, paddlewheels, and engines about amidships, where the hull was most buoyant. This pushed the center of the hull down, while lifting the bow and stern. Second, bulkheads in the hold also resisted the hull's tendency to hog. These two techniques, however, were not nearly as effective as the development and application of hogging chains.

As with most advances in western river steamboat technology, the first vessel to employ hogging chains remains unknown; however, there is no question that hogging chains were the most significant structural development in the history of western river steamboat construction. Hunter's analysis of length-to-depth ratios suggests this advancement took place between 1835

and 1841. Hogging chains were not chains at all, but iron rods which ran the length of the vessel with the ends attached to the bottom of the hull (Fig. 31). The central portion of the chain was carried on the tops of braces just below the boiler deck. The tension on the chain was adjusted with turnbuckles, allowing for continual lifting of the ends of the hull. Hogging chains maintained the shape of the hull, but just as importantly they allowed construction with still lighter timbers. Hogging chains removed the need for heavy, staunch, longitudinal stiffeners in the steamboat's hull, thereby allowing the hull to be more limber. Shipwrights now needed only to build a hull that would hold itself together, not one that had to retain its shape.

Fig. 31. Longitudinal cross-section showing the trussing of City of New Orleans, a sidewheeler built by the Howard Ship Yard and Dock Company in 1881 (Hall, Report on the Ship-Building Industry, p. 192)

Sidewheelers typically had one hogging chain running along the centerline of the vessel, while sternwheelers, because of the excessive weight from the paddlewheel at the stern, had two offset chains. On sidewheelers the aft end of the hogging chain was mounted into the keelson just forward of the sternpost, while the forward end was fastened one quarter the length of the vessel aft of the stem. The forward end of the hogging chains of sternwheelers were mounted into bilge keelsons approximately one quarter the length of the.

229 Hunter, Steamboats on the Western Rivers, p. 96. The average length to depth ratio for 400 to 500 ton vessels increased from 15:1 to 27:1 between 1827 and 1841.
vessel aft of the stem, while the aft end of the chain applied tension to the cylinder timbers, which on sternwheelers projected well past the transom. On both types of vessels, the chains were supported by braces mounted into the bottom of the hull and rose to a level just below the boiler deck. The braces in the aft end of the vessel angled in that direction, while those forward angled toward the bow.

Not only were steamboats susceptible to longitudinal hogging, but the additional weight on the sides of the hull from the guards and paddle wheel assemblies of sidewheelers presented the secondary problem of transverse hogging. This tendency was restrained by cross and knuckle chains, which were similar in design to hogging chains, but were smaller in diameter (Fig. 32). Cross chains were used to support the extremities of the guards, which tended to droop toward the water. Knuckle chains were used to support the sharp bilges, which accepted a great deal of downward force from the superstructure. Both cross and knuckle chains were carried on the top of braces positioned on the keelson. Through the careful arrangement of these devices, the chains effectively lifted the sagging portions of the hull, while the braces, via the downward pressure exerted by the chains that passed over them, pressed down on parts of the hull that tended to lift. By instituting these various trussing systems, shipwrights were able to limit steamboat hogging, while maintaining limberness.

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CONSTRUCTION FEATURES

The following section will highlight basic structural features found in one form or another on the archaeologically investigated western river steamboats. This discussion is necessarily weighted toward vessel hulls, since lightly built superstructures rarely survived in a dynamic riverine environment. The following analysis does not cover every structural element found on western river steamboats, but focuses on those for which there are archaeological data, and those adapted in some way for use on the western rivers.

Keel

A ship's keel is the lowest and strongest principal member of the hull that continues the whole length of the vessel. The keel of the western river steamboat does not entirely meet this definition, but can more accurately be defined as a keel plank, in that the keel did not differ significantly from the planks adjacent to it. Western river steamboat keels were vestigial in nature, and projected no more than 1 or 2in (.03 or .06m) below the bottom of the hull. In sailing vessels, a heavy keel provided structural strength and, because it projected below the
bottom of the hull, prevented leeway. Neither of these functions was applicable to the steamboats of the western rivers.

Western river steamboats of the two earlier periods had keels which projected significantly below the vessel’s hull, but with the advent of hogging chains in the late 1830s or early 1840s this type of keel was no longer necessary. There was no need for the structural strength imparted by a heavy keel, since hogging chains were substituted to counter hogging and sagging. Moreover, the staunch backbone of a heavy keel prevented limberness. The ability to flex was an essential requirement for steamboat hulls, given the frequent groundings to which they were prone. Traditional keels also increased the amount of water a vessel drew, a significant impediment for vessels plying shallow rivers. Countering leeway was also unnecessary for vessels not propelled by the wind. Finally, a protruding keel hampered the sideways maneuverability of the vessel, which was achieved through the manipulation the rudder and both paddlewheels.232

All of the hulls examined for this study were built after the evolution of the western river steamboat was largely complete, and therefore the study of their hulls presents little data regarding keel development. Among the reports of the nine vessels investigated, only three contain specific information about the keel’s construction. The sidewheeler Kentucky had a keel plank, moulded 3 and sided 10in (.08 and .25m). The top of the keel was flush with the inboard face of the garboards, and the keel projected 1in (.03m) below the bottom of the hull. The other two vessels, sternwheelers Cremona and Bertrand, lacked even a keel plank. The plank running along the centerline of the vessel differed in no way from the remainder of the planking.

232Hunter, Steamboats on the Western Rivers, p. 78.
Framing

The framing of any western river steamboat, excluding perhaps some vessels in the 1811 to 1830 period, consisted of flat floors and vertical or nearly vertical futtocks. The floors and futtocks were small, generally moulded 4 to 8in (.1 to .2m), and sided 2 to 6in (.05 to .1m). Room and space at the bow was often decreased relative to the rest of the hull, with the understanding that a strongly framed bow could withstand the impact from driftwood. Still, no attempt was made to make the framing resistant to snag punctures. Data from archaeological examples indicates that, based on construction at the turn of the bilge, framing systems can be broken down into three types: standard chine, chine log, and rounded bilge construction.

**Standard Chine Construction.** Standard chine construction appears to be the most common type found on western river steamboats, and was evident in the hulls of A.S. Ruthven (Fig. 33), J.D. Hinde (Fig. 34), Bertrand (Fig. 35), and 3CT243 (Fig. 36). The floors in this type of framing were dead flat across the breadth of the hull, while the futtocks were vertical, or near-vertical. The chine was braced by a small triangular-shaped timber known as a cocked hat. The cocked hat reinforced the joint between the bottom and the side of the hull by joining the floor to the first futtock. A longitudinally oriented chine clamp was fastened to the cocked hat to reinforce this intersection further.
Fig. 33. Chine construction from A.S. Ruthven (Klopp, et al., The A.S. Ruthven, fig. 19)

Fig. 34. Chine construction from J.D. Hinde (Gearheart and Hoyt, Channel to Liberty, fig. 20)

Fig. 35. Chine construction from Bertrand (Petsche, The Steamboat Bertrand, fig. 76)

Fig. 36. Chine construction from 3CT243 (Stewart-Abernathy, The Ghost Boats, fig. 5.7)
**Chine Log Construction.** To date there is only one known steamer, Cremona, with chine log construction. Given the small data set it is impossible to know if the construction of Cremona was merely an anomaly, or if it represents a widespread construction type of which only one example was known. Cremona’s construction, illustrated in figures 37 and 38, was particularly interesting not only because it differs from any other steamboat yet found, but also because of its similarity to canal boat and barge construction. Cremona’s hull, with its flat bottom and vertical sides joined by a chine log, was indistinguishable in construction from a canal boat. The ends of Cremona’s floors were morticed into the chine log via a wedged dovetail joint. The futtocks were secured by a mortice in the chine log and a notch cut out of the first side strake.

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**Fig. 37.** Cross-sections of Cremona showing the chine log construction (Irió, *Confederate Obstructions*, fig. 15)

**Fig. 38.** Plan view of Cremona’s hull showing the dovetail joint construction (Irió, *Confederate Obstructions*, fig. 14)
**Rounded Bilge Construction.** Rounded bilge construction was noted on three vessels: *Arabia, Kentucky*, and *Black Cloud*. These vessels, all sidewheelers, had flat bottoms and vertical sides, but these two parts of the hull were not joined abruptly by a chine; instead, they made a rounded transition from one to the other. Figure 39, a cross-section of *Kentucky*’s hull and Figure 40, a perspective view of *Black Cloud*’s hull, illustrates this construction technique. Rounded bilge construction was more labor-intensive than either of the aforementioned techniques. Compass timber was required for futtocks spanning the turn of the bilge.

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A cross-section of *Arabia* not included because one does not exist. *Arabia*’s inclusion in this category is based on the author’s inspection of the remains of the stem in the Steamboat *Arabia* Museum in Kansas City.
Keelson

Lacking a substantial keel, the structural importance of the keelson increased. Keelsons can be divided into two categories: keelsons and keelson assemblies. Three of the nine vessels in this survey, Cremona (Fig. 41), Black Cloud (See Fig. 40), and 3CT243, had keelsons composed of only one timber. Keelson assemblies were present on three vessels: Kentucky (see Fig. 39), A.S. Ruthven (Fig. 42), and Bertrand. The J.D. Hinde apparently had no keelson, and no information exists regarding the keelsons of the Caney Creek Wreck or Arabia.

On western river steamboats the keelson's role was not limited to that of longitudinal stiffener and spacer for the floors; it also served as a step for other features. Longitudinal bulkheads running the length of the vessel were typically mounted on top of the keelson, while
this face of the keelson was also commonly notched to receive stanchions supporting the deck above. Braces used to support hogging and cross chains were also stepped into the keelson.

Fig. 41. Detail of Cremona’s keelson (after Irion, Confederate Obstructions, fig. 15)

Fig. 42. Detail of A.S. Ruthven’s keelson (after Kloppe et al., The A.S. Ruthven, fig. 13)
Bilge Stringers

Bilge stringers, also commonly known as bilge or side keelsons, or hold streaks or stringers, were primary fore-and-aft features in a western river steamboat’s hull. These planks ran longitudinally along the inboard faces of the floors, with an average of between six and twelve per vessel. Stringers were generally moulded 2 to 6in (.05 to .15m) and sided 4 to 8in (.1 to .2m). These elements served several purposes. First, they strengthened the frames by firmly holding them in a fore-and-aft line. Second, many bilge stringers were used to mount both stanchions and bulkheads, which might be mortised into and/or toenailed to the inboard face of the bilge stringer. The diminutive dimensions of bilge stringers ensured they did little to counteract hogging and sagging. If the dimensions of these elements were increased sufficiently in an attempt to prevent hull distortion, the result would be increased weight in the vessel’s hull and a loss of flexibility.

Planking

All of the steamboats examined in this study were planked in a caravel fashion. Planking was light with thicknesses ranging from 1¼ to 3in (.3 to .08m). Only one vessel, A.S. Ruthven, showed any unusual planking features. The exterior of this vessel’s hull was sheathed with a 1in (.03m) thick layer of sacrificial planking. This feature was employed to shield the planking from the abrasion and damage caused by frequent groundings and encounters with driftwood. This was the only known example of a western river steamboat with sacrificial planking.

Bulkheads

Longitudinal bulkheads were universal features in western river steamboat construction. These components of the hull helped prevent hogging by creating a wall or
lattice-work of interlocking timbers. At a minimum, vessels had one bulkhead down the centerline, but three or more bulkheads evenly spaced in the hull were common. Two types of bulkheads have been archaeologically documented: solid timber bulkheads and diagonal trussing. Among the vessels of this study, bulkheads were not preserved on Cremona, A.S. Ruthven, Black Cloud, or 3CT243, and the nature of Arabia’s and Caney Creek Wreck’s bulkheads is unknown.

**Solid Timber Bulkheads.** Solid timber bulkheads were represented in the remains of J.D. Hinde and Bertrand. J.D. Hinde had three bulkheads, while Bertrand was fitted with only one (Fig. 43). The bulkheads on both vessels were composed of two structural members. Vertically oriented stanchions were positioned at intervals of 2 to 4ft (2 to 1.22m). The stanchion bases were morticed and/or fastened into the keelson or bilge stringers. The tops of the stanchions were similarly attached to longitudinally oriented deck beams. The planking was the second component of the solid timber bulkhead. It was laid edge-to-edge upon either the port or starboard face of the stanchions. In this fashion a solid wall of timber was created down the entire length of the vessel.

**Diagonal Trussing.** Diagonal trussing was a method commonly used to prevent hogging on ocean-going ships in the mid-nineteenth century. Kentucky’s diagonal bracing (Fig. 44) was fitted in an overlapping pattern of two diagonal timbers and one vertical stanchion. The diagonal and vertical timbers were toenailed to the keelson below, to the longitudinally oriented deck beam above, and the intersection of these timbers was secured with a bolt midway up the stanchions. The application of diagonal trussing was best described in Murray and Murray in *Ship Building and Steam Ships*. “The introduction ... of diagonals of a fixed or unalterable length into any piece of framework will tend to prevent alteration of form, and it
will be perceived that the duty required of the two diagonals in resisting any change is different, the one being required to resist extension, and the other to resist compression.²³⁴

Fig. 43. Photograph of Bertrand’s hull during excavation. The solid timber bulkhead running along the centerline of the vessel was a prominent feature (Petsche, The Steamboat Bertrand, inset)

²³⁴A. Murray and R. Murray, Ship-Building and Steam Ships, p. 87.
Deck Beams, Decking and Guards

The shallow hull of the western river steamboat limited the storage of cargo in the hold. Consequently most of the cargo was carried on the main deck, requiring that this area be expanded as much as possible. The cargo capacity of the main deck was significantly increased by the overhanging guards. On sidewheelers, guards typically added 50 to 75 percent of breadth to the main deck relative to the breadth of the hull, while on sternwheelers they were much smaller. On sidewheelers, the width of the paddlewheels determined the width of the guards. Consequently, as the length of paddlewheel buckets progressively increased throughout the period, so did the width of the guards. On sternwheelers, the guards were generally much smaller, but the width of the hull was proportionately beamier.

Decking is rarely preserved on shipwrecks, but due to the tendency of the rivers in the Mississippi Basin to quickly bury hull remains, this level of preservation is not uncommon for

235 Hunter, Steamboats on the Western Rivers, p. 93.
western river steamboats. Four of the eight investigated steamboats had portions of the
 decking and/or guards preserved. Of these vessels, Arabia, Kentucky, Bertrand, and Black
 Cloud, only the report of the steamboat Kentucky supplied details regarding the arrangement
 of these structures.

Kentucky’s deck beams had sided and moulded dimensions of 2 to 2.5in (0.05 to .1m)
and 6in (.15m) respectively, and were spaced at intervals ranging from 2ft 4in to 2ft 6in (2.3
 to 2.5m). To span the breadth of Kentucky’s deck, the deck beams were composed of several
individual timbers joined by lap joints. The lap joints were secured with iron fasteners. The
preserved decking from the main deck was composed of pine 3½ to 6½in (.1 to .2m) wide
and 1in (.03m) thick.

Trussing

Between 1835 and 1841, hull distortion caused by the extreme length-to-breadth ratio
led to the application of hogging chains to vessels’ hulls. Archaeological remains of trussing can
consist of the chains themselves and the footling and braces used to support and brace the
chains.

Footlings. A footling was a longitudinally oriented wooden structure, positioned on
top of the floors, used to hold the foot of a brace and distribute its downward force. The
hogging chains on sidewheelers were arranged so that most of the footlings were just port
or starboard of the centerline, while on sternwheelers footlings were also found near the bilges
to support the braces from the two longitudinal hogging chains.

\[236\] The sidewheeler A.S. Ruthven has a footling positioned just forward of amidships near the port edge
of the hull. This structure may have been used to support the weight of the engines.
Footlings were documented on three of the eight vessels in this survey. *Kentucky's* documented footling (see Fig. 25), located adjacent to and on the starboard side of the keelson, was 7 ft long (2.13 m), sided 4 in (.1 m) and moulded 9½in (.2 m). Both the tops of the forward and the after ends of the footling were rounded, and the outboard face of the structure was notched to fit over the floors. The footling had a mortice cut into its inboard face to receive a brace. The footlings on A.S. *Ruthven* and *Bertrand* (Fig. 45) were similar to each other. Both were trapezoidal in shape and were notched to receive a brace.

**Fig. 45.** Plan view and profile of a footling from A.S. *Ruthven* (from Kloppe et al., *The A.S. Ruthven*, fig. 18)

**Braces.** Braces were wooden posts used to support the hogging chains. The foot of the brace was morticed into a footling, while the chain was suspended over the top of the brace. Depending on the angle of the chain above, the brace was oriented vertically or canted forward or aft. The remains of *Kentucky* contained two preserved braces, but this type of structural feature was not preserved or documented on any of the other vessels. On *Kentucky* a 6 in by 6 in (.15 m) brace, used to support a cross chain, was mortised into the inboard face of both the keelson assembly and a footling. The mortise, which was divided evenly between
these two structural members, was positioned in that manner to better distribute the downward force of the brace throughout the hull. The larger of the two braces measured 7in by 7in square (.18 by .18m). The brace rose from the bottom of the hull at a 58-degree angle toward the after end of the vessel, a significant tilt because it indicated the brace supported the longitudinal hogging chain rather than a cross chain. This angle allowed more force to be exerted on the brace than if it had been oriented vertically.

**Hogging Chains.** In an archaeological context, the types of hogging chains (longitudinal, cross, and knuckle) can be differentiated by their sizes, numbers, and positions. Longitudinal hogging chains are larger and less common than either cross or knuckle chains. Kentucky’s longitudinal hogging chain was 2in (.05) in diameter, while its cross chains were 1in (.025m). Cross chains are common in steamboat sites, although they are typically out of context. During the working life of the steamboat they span the distance between the main deck and the boiler deck; however, no archaeological example of a steamboat has been preserved up to the boiler deck, thus the cross chains are in a state of disarray. Knuckle chains are also a common find, although their location in the bottom of the hull allows for better preservation. In order to adjust tension, all chains were fitted with turnbuckles (Fig. 46).

![Fig. 46. Drawing of a turnbuckle from one of Kentucky's cross chains (courtesy U.S. Army Corps of Engineers)]
Features relating to the trussing of western river steamboat hulls are some of the most common finds on steamboat sites, attesting to their importance in steamboat construction. The following section of this study, a series of contemporary steamboat photographs, illustrates a number of these features. In particular, figures 54 and 55 illustrate steamboat trussing quite well.

CONSTRUCTION PHOTOGRAPHS

The understanding of steamboat construction has been greatly aided by the development of photographic technology in the latter half of the nineteenth century. The following section contains contemporary photographs used to illustrate some of the above-detailed construction features. The first known western river steamboat captured on film was in 1848 by photographer Charles Fontayne (see below). In the following decades thousands of photographs were taken of these vessels, most showing a steamer traveling on a river or tied up at a wharf. A scant few depict steamboats being built; nearly all that do were taken by James E. Howard, of the Howard Ship Yard and Dock Company. James Howard received a camera kit in the late 1880s, and subsequently began visually documenting the process of building and launching steamboats. Although these photographs were taken after the period of this study, they are no less instructive. Construction techniques had not radically changed in the decades between 1860 and the time the photographs were taken.

Figure 47 is a small section of Charles Fontayne’s daguerreotype The Cincinnati Panorama of 1848. The full work is contained in 8 plates, and shows the entirety of Cincinnati’s waterfront. Many steamboats are present in this image, but these two, Embassy

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23). Custer, “Building the Belles of the Western Rivers,” W&L 64 (1985): 67. This collection is currently housed at Inland Rivers Department at the Public Library of Cincinnati and Hamilton County.
and *Car of Commerce*, show the greatest amount of detail. *Car of Commerce* was built in Murraysville, Virginia in 1848, and was lost in December of the same year after being wrecked by the Louisville Falls.\(^{238}\) The first feature of note on this steamer is the absence of the Texas. The lines of the vessel are quite smooth with both the bow and stern having 2 to 3 ft (.61 to .91 m) of sheer. This gentle curve is paralleled in the boiler and hurricane decks. The *Embassy*, on the left, was not on the rolls until 1849, but was clearly built in 1848. Her most noticeable feature is the Texas. In subsequent years the Texas would become much longer, extending much of the length of the hurricane deck, but at this point in steamboat development it was still an awkward, boxlike attachment.

![Image of steamboats](image)

**Fig. 47.** A section of plate 2 from Fontayne's *The Cincinnati Panorama of 1848* showing the steamboats *Car of Commerce* and *Embassy* (courtesy of the Inland Rivers Library)

An excellent photograph taken by James Howard in 1890 (Fig. 48) shows the hull of the *City of Hickman* while under construction.\(^{239}\) This vessel was a sidewheeler with a length


\(^{239}\)The *City of Hickman* was launched in 1890 by the Howard Ship Yard and Dock Company, Jeffersonville, Indiana. The vessel was a sidewheeler, 285 ft x 44.5 ft x 9.5 ft (86.9 x 13.6 x 2.9 m).
of 285ft (86.9m), a breadth of 44.5ft (13.6m), and a depth of 9ft (2.7m). Most striking are the dead flat floors, used to achieve maximum displacement for a given area, thereby reducing the vessel’s draft. Also noteworthy are the chines, with the standard chine method used to join the bottom of the hull to the sides. Other interesting construction features are the lines of tar along the inboard faces of the floors where the bilge stringers will eventually be placed. Presumably the tar was used to prevent rot between the floors and the stringers.

Fig. 48. Photograph from 1890 showing City of Hickman while under construction at the Howard Ship Yard and Dock Company (courtesy of the Howard National Steamboat Museum)

Figures 49 and 50 show the boiler deck of the Alton, built by the Howard Shipyards in 1906 and lost due to ice in Paducah, Kentucky in 1918.\textsuperscript{240} In the first photograph the cabins have been framed out, and some of the elaborate woodwork has been finished. Note the

\textsuperscript{240}Way, Way’s Packet Directory, p. 16.
small dimensions of the timbers used in construction. The following photograph shows the saloon with adjoining cabins upon completion.

Fig. 49. Photograph of Alton’s partially finished saloon (courtesy of the Howard National Steamboat Museum)

Fig. 50. Photograph of Alton’s saloon upon completion (courtesy of the Howard National Steamboat Museum)
The following series of five photographs (Figures 51 through 55) from the Way Collection, located at the Inland Rivers Collection of the Library of Cincinnati and Hamilton County, shows Otto Marmet being built in 1897 at Raymond City, West Virginia. Figure 51 shows the vessel with all of its framing completed, and the sheer strake attached. An inspection of the stern reveals that it is a sternwheeler, based on the three sternposts and the full shape of the stern. The framing is of the standard chine type, with a model bow. Note the steambox in the foreground.

![Image of Otto Marmet](image)

Fig. 51. Photograph showing Otto Marmet in the early stages of construction (courtesy of the Inland Rivers Library)

Figure 52 shows Otto Marmet further along in its construction. A clamp has been fastened just below the tops of the futtocks. This clamp will support the deck beams, as grown knees were not commonly used in western river steamboat construction. Also noteworthy are the multiple bilge stringers placed longitudinally in the hull.
Figure 52. Second photograph in the Otto Marmet building series (courtesy of the Inland Rivers Library)

Figure 53 shows the hull of Otto Marmet as nearly complete. Especially significant in this photograph are the outrigger beams. These beams, which are set into the sheer strake, will form the base of the guards. Note how diminutive these structures are; clearly the guards will be very small, thus its draft will be low in proportion to its length. The deck beams show a slight amount of camber that will allow water to flow off the deck.

Fig. 53. Third photograph in the Otto Marmet building series (courtesy of the Inland Rivers Library)
Figure 54 shows the installation of the vessel's bracing. Two sets of three braces are used to support the two principal longitudinal hogging chains. These braces angle toward either the bow or the stern to more effectively take the downward force from the chain. A close inspection of the after portion of the vessel shows a series of lower hogging chain braces that will eventually support the paddlewheel with another pair of chains.

![Image of a vessel with bracing](image)

**Fig. 54.** Fourth photograph in the Otto Marmet building series (courtesy of the Inland Rivers Library)

The final photograph of Otto Marmet (Fig. 55) shows the vessel just before launching. Presumably it will be floated down to Wheeling, where the machinery will be installed and the superstructure completed. This photograph shows that the vessel has been trussed, and the stanchions for the boiler deck have been fitted.
MECHANICAL CHARACTERISTICS

The mechanical characteristics of steamboats of the mature phase did not fundamentally differ from those at the end of the Developmental Phase. By 1835, the high-pressure engine powered by a battery of boilers was both universally adopted and fully developed in the essential points of its construction. Chapter V described the details of boiler construction, therefore the following discussion of boilers will not repeat the information contained there, but will present the details of boiler evolution during this period. The analysis of the high-pressure engine will also build on the previous chapter, and will detail more of the specifics about how this engine was constructed and operated.
Boilers

During the 1830s and early 1840s the trend in steamboat machinery was toward more boilers, with six or even nine common by the fourth decade. The disadvantage of the extra weight in iron and water of so many boilers was subsequently realized, however, and in the following decade the trend was reversed. By 1850, four or five boilers were again typical, with similar diameters, but with an increase in length reaching 28 to 30ft (8.53 to 9.14m) (Fig. 56). 241 Boiler shells in the 1830s had thicknesses of 1/5 to 1/6in, (.5 and .4cm) but were increased to 1/4in (.6cm) by 1850. 242 Flues, tubes allowing the passage of hot gases from the furnace through the boiler, continued to be used during this period. In the years following 1860, the number of flues increased to up to six per boiler, but two was the standard between 1830 and 1860.

241 Walworth, The Wheeling Bridge Case, pp. 635-639. This information is based on a table of measurements of steamboats constructed by Israel Dickenson.
242 Walworth, The Wheeling Bridge Case, p. 453. This information was taken from the testimony of Professor John Locke.
The Doctor. Through much of this period water was still supplied to the boilers using the feed water pump, described in the preceding chapter. This method was slowly phased out with the advent of a small, independent, steam-driven flywheel pump in the early 1840s (Fig. 57). This pump was known as the doctor because of the hope that it would cure all the evils of the western river steamboat by supplying a steady stream of water to the boilers, thereby preventing explosions. The doctor also worked the bilge pumps and supplied the hose in case of a fire. Although the doctor did reduce the number of boiler explosions, its impact was lessened by because it was not widely used until after 1850, and even then it was not employed on the smallest class of steamboats.

Although the manner in which this device worked is complicated to explain, in reality it was a simple piece of machinery. The working parts of the machinery were easily accessible and could be repaired by most engineers. The doctor was on the main deck just aft of the boilers. Its motive power was received via an auxiliary steam line stemming from the boilers. Steam was injected into the vertically oriented steam cylinder, forcing the piston and connecting rod to work. A connecting rod transferred its up and down motion to one end of a side lever; a rod connected to the side lever turned the central feature of the doctor, a flywheel. Once in motion, the heavy cast iron flywheel moderated the speed of the machinery by its weight and the inertia therein contained. The motion of the side lever additionally

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244 Rees, IME 14 (1909): 345.
245 Walworth, The Wheeling Bridge Case, p. 49. This information is from the testimony of Jacob Hazlep, a steamboat pilot.; F. D. Herbert, “Steamboating on the Mississippi,” IME 12 (1907): 188.
246 The testimony of William Stewart, a steamboat builder, indicates that the doctor was in common use by 1850 on the largest class of packet boats on the Ohio River, but there were more small steamboats that did not use it, than those that did (Walworth, The Wheeling Bridge Case, p. 531.)
worked two sets of pumps, lifting and force pumps. The single acting cold water or lifting pumps drew water from the river and forced it into the heaters. The heaters were composed of riveted, wrought iron shells with cast iron heads. Here the cold water was heated by the engine's exhaust steam as it passed through the heater via a central pipe. The hot water or force pumps took the water from the heater and transferred it into the boilers.\footnote{Rees, IME 14 (1909): 344.; and International Correspondence Schools, The Machinery of Western River Steamboats, pp. 55-57.}

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Fig. 57. Drawing of a doctor from the late nineteenth century (Ward, TSNAME 27 (1909): pl. 38)
Natural Versus Artificial Draft. The process of combustion powered steamboat machinery, with wood being the typical fuel; however, coal was used as well. The ability to regulate the combustion of the fuel was important: increased fuel consumption translated into higher steam pressures and more power to the engine, while reduced consumption meant less power but a savings in the cost of fuel. In the Developmental Period, air was conveyed to the furnace by a technique known as natural draft. In the 1840s and 1850s other methods were applied with varying levels of success, but none of these techniques replaced natural draft; many contemporaries believed this was due to the stubborn nature of western engineers.

The first of these techniques for creating artificial draft were steam blowers. Here a small amount of steam was diverted from the steam line that lead to the engine. This steam was vented into either the flues or the chimneys, thereby diminishing the specific gravity of the gases around it, and aiding the draft of the furnace.251 The diverted steam was normally built up in a steam box and injected into the flues or chimneys by way of a small pipe with a perforated end. Steam blowers were not widely adopted on the western rivers because many engineers believed they burned out the flues and breeching. The venting of steam into the flues and chimneys also tended to promote corrosion, thus shortening the life span of these features.252 The diversion of steam from the engines to the steam blowers resulted in diminished power to the engines. Not only did steam blowers need frequent repair, but many engineers believed they burned more fuel and depleted the water supply in the boilers more rapidly.253

251 Walworth The Wheeling Bridge Case, pp. 445 and 530.
252 Ibid., p. 445.
253 Ibid., pp. 58, 60, and 69.
Fan blowers, the second method of artificial draft, were also never widely adopted on western rivers, although they did have supporters. In this method a fan powered by an auxiliary steam line from the boilers was used to force a flow of air into the furnace. The fans were normally at the after end of the ash pan, and made approximately 700 revolutions per minute.\textsuperscript{254} The fan blower worked on the same principle as natural draft, but could be made much more intense, if desired. This innovation was not without its drawbacks, both real and perceived. Fan blowers were costly, heavy, large, and required frequent repair.\textsuperscript{255} Some engineers complained that the fan blowers were loud, and the increased air flow forced more sparks and soot up the chimneys.\textsuperscript{256} They also took power away from the engines, thereby slowing the vessel. Finally, the fan blowers concentrated the heat of the fire on the grate bars, causing them to burn out.

For several reasons, neither steam nor fan blowers ever entirely superceded natural draft. Most important of these reasons was the strong prejudice of the engineers against using any type of new technology. By the 1840s both the engines and boilers of western river steamboats were well-established, and most engineers were reluctant to radically alter a device which already performed its duty well. Furthermore, steamboat machinery had been made as cheap, light and simple as possible. Introducing a complicated, expensive device to do a task that was already performed at no cost was not acceptable to most engineers.

\textsuperscript{254}Ibid., pp. 71 and 73.
\textsuperscript{255}Ibid., pp. 58 and 445.
\textsuperscript{256}Ibid., p. 57.
Chimneys

Consistent with most other features of the western river steamboat, the dimensions of the chimneys increased throughout this period. By 1850 chimneys commonly rose at least 45 ft (13.7 m) above the boilers, and on larger vessels 80 ft (24.4 m) was not unusual.\textsuperscript{257} The diameter of the chimneys also increased, with typical diameters being between 42 and 60 in (1.1 and 1.5 m). To construct a chimney, its diameter was calculated by determining the aggregate sectional area of the boiler flues and multiplying that number by either 2.5 or 3. That number divided by two would be the sectional area for each chimney.\textsuperscript{258}

The last significant development in the construction of chimneys occurred in the mid-1830s with the addition of hinges. These hinges, always made of cast iron, allowed the upper portion of the chimney to be lowered. This feature was a direct response to the increasing number of relatively low bridges across the western rivers, especially the Ohio River. The task of building bridges high enough to allow steamboat traffic to pass beneath them during periods of high water proved impractical. Chimneys designed to be lowered were built stronger than those intended to be static. They were built of thicker sheet iron, and were reinforced by vertically oriented iron bars running along the inside of the chimneys.\textsuperscript{259}

\textsuperscript{257}Walworth, The Wheeling Bridge Case, p. 419.
\textsuperscript{258}Ibid., pp. 520 and 571.
\textsuperscript{259}Ibid., pp. 66, 87, 415, and 541.
Engines

The engine of the western river steamboat (Fig. 58) was not an awe-inspiring sight; it had little if any bright work, and generally lacked the refinement that was common in other types of steamboat engines. Despite its plain appearance, it was well adapted to the function it served. It was a light, powerful, inexpensive, and easily maintained machine.

Early western river steamboats had one engine, but after 1840 many larger packets were equipped with two, each working its own paddlewheel. Two steam engines provided more power, but the primary advantage was the maneuverability provided by two engines. The ability to stop or back one paddlewheel while keeping the other going forward was essential in the navigation of narrow, winding rivers. Each engine was located near the edge of the hull, thereby leaving open for cargo the space between the engines. Steam pressure slowly increased through the years, and by 1850 pressures of between 130 and 160 pounds (59.0 and 72.6kg) per square inch (.025m) were typical for packets on the Ohio River.

The steam engine in the western river steamboat rested on a heavy timber frame, known as the cylinder timbers. The base of the cylinder timbers was notched into the floors in the bottom of the hull and spanned many frames, thereby spreading the weight of the engine across a large area of the hull. The cylinder timbers not only supported the engines, but continued aft, angling upward, so that they also carried the paddlewheel shaft.

261Merrick, JFI 23, no. 5 (1852): 344. In 1838 it was noted that both one and two engine boats were in existence (Stevenson, Sketch of the Civil Engineering of North America, p. 153.)
262Gilman, JFI 24, no. 3 (1852): 209.
263Walworth, The Wheeling Bridge Case, p. 636-639. This information is based on a table of measurements of steamboats compiled by Israel Dickenson.
264Ward, TSNAME 17 (1909): 85; Bryan, TASME 17 (1896): 394.
Fig. 58. Plan and profile view of the high-pressure engine of Buckeye State. A- Cylinder, B- Exhaust valve cf H- Lifting pump, I- Escape pipe to the wheelhouse, K- Pitman, L- Crank, M- Intake valve chests, N- Intake sit (Tredgold, Machinery Used in Steam Navigation, Volume II, Part II, pl. 5)
C- Exhaust side pipe, D- Exhaust valve levers, E- Steam pipe, F- Throttle-valve chest, G- Heater, H- Cylinder, I- Intake valve levers, J- Rock shaft, K- Paddlewheel shaft, L- Yoke, M- Piston rod, and N- Crosshead
The heart of the steam engine was its cylinder. The cylinder was oriented just above horizontal, at an angle sufficient to intersect the center of the paddlewheel shaft. Cylinder size increased considerably in the early years of steamboating, with the average cylinder diameter of 20 in (0.51 m) in 1827 increasing to 28 in (0.71 m) by 1838.265 After 1840, cylinder diameters stabilized primarily due to the trend toward using two engines.266

Admission and exhaust of steam into and out of the cylinder was effected in four valve chests and regulated by the poppet valve system (Fig. 59).267 In this system the cylinder was cast with two nozzles at each end, each nozzle having a valve chamber. There was therefore one chamber at either end for the admission of live steam, and one at either end for the exhaustion of steam.268 During each stroke of the piston, steam was admitted to one end of the cylinder, and simultaneously exhausted from the other. The steam being admitted was then cut off at some point in the stroke, and allowed to expand for the remainder. This process then repeated itself from the opposite end of the cylinder.269

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265Water, HD 25th Congress, 3rd session, 345 (1838):321-324. This information is based on statistics recorded for the construction of steamboats in Louisville, Kentucky between 1819 and 1838.
266Hunter, Steamboats on the Western Rivers, p. 143.
267Poppet valve and puppet valve both appear frequently in the literature.
Fig. 59. Cross-section of a steam cylinder equipped with the poppet valve system. A- Valve levers, B- Wipers, C- Cylinder, D- Steam pipe, E- Piston rod, and F- Poppet valves (Ward, TNSAME 17 (1909): pl. 48)

The timing of the poppet valves was governed by two cams on the paddle wheel shaft. The cams, oblong discs mounted on the paddle wheel shaft, created an oscillating motion when the paddlewheel shaft turned. This oscillation was transformed into a fore-and-aft motion by an iron frame, or yoke, within which the cams were contained. In turn, the yoke was welded to a long, wrought iron bar called the rock shaft. The end of the rock shaft ended at a point near the middle of the engine cylinder. Here it was fitted with a double wiper, the alternating motion of which lifted the levers and opened or closed the valves on the cylinder. ²⁷⁰

Thus the rotary motion of the paddlewheel caused the cam to oscillate, giving a reciprocal motion to the yoke and rock shaft, and finally causing the wipers to either lift or let fall the valves on the cylinder.

Regulating the power applied to the engine was as simple as managing how much steam was injected into the cylinder. This could be manually controlled by inserting a 2½in

²⁷⁰Russel, TINA 2 (1861): 125.
(6.4cm) square billet of wood, called the club, between the rocker arm and the lever which lifted the inlet valve. Inserting the club at the proper time provided additional steam to the cylinder, and therefore, extra energy to the paddle wheel.\footnote{Merrick, \textit{Old Times on the Upper Mississippi}, pp. 41-42.} Alternately, the full stroke cam could be employed (Fig. 60). This cam allowed live steam to be fed into the cylinder for the entire length of its stroke. The full stroke cam was used at times when maximum power was needed, such as starting from a complete stop or ascending rapids. Under normal operating conditions the one-half, five-eighths, or three-fourth stroke cam was employed. These cams cut off the steam at various positions within the stoke and allowed the steam to push the cylinder by expansion through the remainder of the stroke.\footnote{Ward, \textit{TNSME 17} (1909): 85.} The use of the cut-off cam, as these latter types were known, resulted in considerable fuel savings.

Fig. 60. Profile of a full stroke cam and yoke (Russel, \textit{TINA 2} (1861): 124)
The reciprocal motion of the piston was turned into the rotary motion of the paddlewheel through a series of simple devices. One end of the piston rod was welded to the piston; the other end had a U-shaped bracket affixed to it. This bracket, known as the crossthead, was fitted with a wrist pin. This wrist pin was punched through the end of the connecting rod, known on western river steamboats as the pitman, thus allowing the pitman to pivot.273 The construction of the pitman was unique to western rivers; it was composed of a wooden timber, most commonly pine, tapered at each end with two wrought iron straps bolted around the edges.274 The aft end of the pitman connected to the crank on the paddlewheel shaft. In practice, steam was injected into the cylinder, forcing the piston inside the cylinder to move. As steam pushed the piston, the piston rod was also forced to move. The movement of the piston rod was transferred to the pitman via the wrist pin. The wrist pin allowed the pitman to rotate on that axis. The aft end of the pitman was connected to the crank on the paddlewheel shaft, which was compelled to move in a circular fashion by the pitman. As the pitman rotated the crank, the paddlewheel turned.

Upon completion of each stroke of the piston, steam was exhausted through a metal cylinder, known as the coughing box or feed water heater, used for heating the water before it was fed to the boilers.275 This interesting device was a cylindrical shell of either rolled iron or copper, enclosed at both ends. It was laid on its side, allowing exhausted steam from the cylinder to enter at its underside and cold river water at its topside. The interior contained a series of iron or copper plates oriented horizontally and separated from each other by 3 to 5 in

274 Russel, TINA 2 (1861): 124; and Bryan, TASME 17 (1896): 395. The length of the pitman was in proportion to the length of the stroke. In 1840 the pitman was three and one half times the stroke (Hodge, The Steam Engine, p. 240.)
(7.6 to 12.7 cm) of open space. These plates spanned the entire length of the heater, and alternating ends of the plates had holes cut into them. The effect of this system was such that water was sent into the top and was forced to descend along all of the iron plates in a lateral, back and forth fashion until it reached the bottom. While the water cascaded down through the levels, steam was forced upward, thus imparting its heat to the water. Upon reaching the bottom of the heater, the water was fed via the feed water pump or the doctor to the boilers.\textsuperscript{276}

Often during this process all of the steam would be condensed; if it was not it could still be put to use. Excess steam could be piped into the paddlewheel boxes to prevent ice from forming on the paddlewheels or into the chimney to aid the draft of the boilers. The steam might also merely be allowed to escape up through a small chimney past the hurricane deck.\textsuperscript{277}

**Paddlewheels**

Paddlewheels grew in nearly every dimension during this period. Ruben Miller, a steamboat builder and owner, estimated that in 1840 the average diameter of steamboat paddlewheels was 18 to 22 ft (5.5 to 6.7 m), while only ten years later it was 25 to 31 ft (7.6 to 9.5 m).\textsuperscript{278} Additionally, the width and depth of the buckets were increased, although not in proportion to the diameter.\textsuperscript{279} Figure 61 shows Bates' schematic of a paddlewheel with significant features labeled.

\textsuperscript{278}Walworth, *The Wheeling Bridge Case*, pp. 88-89.
\textsuperscript{279}Ibid., pp. 403, 426, and 532.
Fig. 61. Diagram of a paddlewheel with the major features labeled (after Bates, Steamboat Cyclopaedium, p. 93)
The center of a paddlewheel was a cast iron apparatus known as the flange. The outer circumference of the flange contained pockets into which the arms were secured. The arms were hewn to fit snugly in the pockets, and to expand for an even tighter fit when wet. Spacing between the arms was maintained by several devices. The most important of these was a pair of wrought iron circular bands bolted to the arms. Each of the iron circles was fastened to either the interior or exterior face of the arms. The gaps between the iron circles were filled with wooden blocks, locked in place by keys driven into the space between the arm and the wooden block. This iron and wood circle was paralleled by one or more rows of wooden blocking. The arms were also locked into place by small wedges of wood, known as cocked hats, fastened between the arms just outside the flange. The final features of the paddlewheel were its buckets, which provided resistance in the water, which in turn drove the vessel. These were simple planks of wood bolted to the arms, with a batten used to keep the bolt from pulling through the bucket.280 Buckets were frequently damaged, and several spares were carried onboard at all times.

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VII: CONCLUSION

Between 1811 and 1860, the trans-Appalachian West underwent a fundamental transformation. As far as Europeans and European-Americans at the beginning of the nineteenth century were concerned, the West, though it showed potential, was an immense wilderness having little substantive economic import or consequence. By the close of the third decade of the century, however, a new steam technology in the form of the western river steamboat had entirely changed the regional landscape and character.

In the early years of American nationhood, a trickle of settlers made their way into the lands west of the Appalachian Mountains. It was a region inhabited mostly by Native Americans, with a few rough backwoodsmen and hardscrabble farmers carving out an existence in a region entirely removed from European refinement. These settlers realized early the value of the Mississippi Basin's rivers. Two general types of vernacular craft, flatboats and keelboats, were developed to transport the West's agricultural products down river to New Orleans, where their cargos were transshipped to markets around the world. These vessels were adequate for downstream travel, but the upstream journey was much more difficult. The simple flatboat with its box-like hull was sold for lumber upon arriving in New Orleans, while the diminutive keelboat was packed full of trade goods for the grueling 2000 mile (3218.5km), or more, upstream journey. This was a hindrance to the West's ability to import the items its citizens demanded; the problem lay not in supply, but in transportation. The difficulties of importing trade goods into the West directly affected the downstream flow of commodities. Without a corresponding influx of manufactured articles, the export of goods and the development of the region in general were hampered.
The first steamboat was introduced to the western waters in 1811 by Robert Fulton, but neither this steamboat nor those of the following decade had any significant economic effect on the region. The early steamboats were generally propelled by low-pressure engines contained within deep hulls; their machinery and hull type were entirely unsuited to the shallow and swift western rivers. They often had features such as sails, bowsprits, below-deck cabins, and figureheads, vestiges of oceangoing vessels soon recognized as useless and subsequently discarded.

In the 1820s and 1830s the steamboat was rapidly adapted to western river conditions through a process of trial and error by regional shipwrights and steam engine builders. These craftsmen pragmatically undertook the job of creating a vessel type which could successfully travel on the swift and shallow western rivers. Steamboat hulls became increasingly shallow and flat-bottomed, necessitating the use of multiple decks above the waterline, while the powerful high-pressure steam engine was universally adopted as the power plant of choice. The number of trees consumed by the inefficient high-pressure steam engine was equaled only by those required to build the short-lived steamboat hulls. In a region where timber, coal, and iron were plentiful, the conservation of natural resources was never a limiting factor in the construction and operation of steamboats; in fact these regional attributes helped dictate the form and machinery of the steamboat.

The consequences of the western river steamboat were numerous, affecting society at all levels. The influence of the steamboat must be viewed in relation to the social and economic upheaval engulfing the country at the time. This movement, known by historians as the Market Revolution, changed the American societal framework from one of subsistence farming to market-oriented agriculture. Agriculture suddenly had the potential to create wealth. The Market Revolution created outlets for producers to sell their excess goods, but
new transportation systems were necessary to provide access to the market for the majority of the population. The advancements in transportation which both facilitated and were facilitated by the Market Revolution are collectively known as the transportation revolution. The individual transportation improvements included better roads, canals, steamboats, locomotives, and bridges. All contributed to the economic integration of the United States, especially the states east of the Appalachian Mountains. The West, however, presented a more challenging set of problems when it came to improving transportation. The region itself was geographically enormous, sparsely settled, and densely wooded. These characteristics did not lend themselves to intensive and often expensive building projects such as canals, railroads, roads, and bridges. The steamboat was an ideal technology, however, because it worked on an existing pathway: the trans-Appalachian West's extensive navigable river system. Not only did the steamboat conveniently take advantage of a widespread network of rivers, but steamboats were much less costly and labor intensive to build and operate, and more efficient, than other modes of transportation.

What the steamboat did require, however, was a structure adapted to the conditions on western rivers. The hulls became entirely flat-bottomed, with multiple decks rising high above the waterline. In the late 1830s or early 1840s hogging chains were first applied to western river steamboats. These devices prevented the hull from hogging or sagging, thereby allowing shipwrights to build vessels with lighter timbers. This reduced the weight of the vessel and the amount of water it drew while allowing the tonnage of individual steamboats to increase significantly. The ability of the steamboat to carry massive amounts of freight facilitated its use in the transportation of cotton. The production of cotton was one of the most profitable sectors of the American economy up through the Civil War, and the steamboat was
a crucial link in its transportation and trade. By the 1840s and 1850s the great majority of the
West's commerce was carried by western river steamboats.

Western river steamboats have disappeared from the rivers of the Mississippi Basin, but
their remains are scattered throughout that region. The number of steamboat wrecks in the
Mississippi Valley is a matter of mere conjecture, but the quantity is at least in the hundreds,
perhaps more than one thousand. In the coming years our understanding of steamboat
machinery and hull construction will undoubtedly grow through continued archaeological
study of hulls, boilers, engines, and related equipment.

One characteristic of the Mississippi River and many of its tributaries, namely their
predisposition to meander, has caused main river channels to shift away from wrecks, leaving
them cut off and deeply buried, often far from the current river channel. The steamboats
*Arabia*, *Kentucky*, and *Bertrand* were all subject to this post-depositional pattern. The
evacuation of these steamboats proved exceedingly difficult due to both the amount of
sediment under which they were buried, and the constraints imposed by working below the
watertable. The vessels and their cargo, however, were in an ideal state of preservation
because they were sealed in an anaerobic environment. These excavations revealed intact
structural components up to the main deck, and an archaeological wealth of well-preserved
cargo. It is the author's belief that the western river steamboats buried and submerged in the
nation's interior contain the most significant and complete collection of nineteenth century
material culture in the country.

This study has sought to construct a groundwork for the archaeological study of western
river steamboats by meshing the historical record with archaeological data. Many gaps in our
understanding of western river steamboat construction and machinery stem from the limited
number of archaeologically excavated vessels and the absence of any archaeological data from
the years prior to 1850. The potential information to be gained from these sites is not, however, limited to the details of ship construction. Details about passengers and cargo, and information on broader topics such as western expansion, socioeconomic trends, and gender and ethnic issues can all conceivably be gleaned from steamboat wrecks. Certainly, future archaeological studies will uncover much that we did not know.
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GLOSSARY

Abaft- a directional term meaning toward the stern.

After- behind.

Alluvial- relating to or composed of clay, silt, sand, gravel, or similar detrital material deposited by running water.

Amidships- located in the center of a vessel.

Arm- the spoke of a paddlewheel.

Bar- a riverbed obstruction composed of sand or gravel.

Beam- width of the hull.

Berths- cabins containing one or more beds, or the beds themselves.

Bilge- bottom of the hull of a ship.

Bilge pump- device for pumping water out of ship's hold.

Bilge stringers- longitudinally oriented timbers that run on the tops of the frames (or ribs) of a ship.

Boiler- metal tank filled with water which is heated to produce steam. The steam is used to power a steam engine.

Boiler deck- the second deck, the one above the boilers.

Bow- the forward part of a boat.

Bowsprit- forward angling spar in the bow of a vessel to which the head gear (sails and rigging) are attached.

Braces- timber posts used in connection with the hog chain system to hold the hull in shape.

Breeching- sheet metal connecting the boilers and the chimneys.

Bucket- the paddle of a paddlewheel.
Bulkhead- a partition or wall.

Cabin- an interior room containing sleeping berths.

Canted- angled.

Camber- the athwartships curve of a deck.

Capstan- a rotating cylinder oriented vertically used for lifting anchors or hauling cables

Chimney- sheet metal tube used to carry smoke away from the vessel and create a draft in the furnace.

Chine- an angular meeting between the bottom and sides of the hull.

Cocked hat- 1. a triangular wooden block used to brace paddlewheel arms. 2. a triangular timber used to brace the floors and futtocks where the bottom of the hull meets the sides.

Collar- lead washer used to make boiler joints steam tight.

Compass timber- curved timber in ship construction which is derived from the similarly-curved portions of a tree.

Condensing engine- a type of steam engine, normally of low-pressure which condenses the steam in the cylinder.

Cordelling- method used to move a keelboat in which the crewman towed the vessel from the riverbank.

Cotton packet- a sidewheel or sternwheel steamboat modified to carry cotton with an extra wide main deck and very narrow boiler deck and cabin.

Counter stern- type of stern with an arch forming an overhang abaft the sternpost.

Crank- the bent part of a shaft or axle through which reciprocating motion is transformed into rotary motion, or vice versa.
Cross chains- a system of wrought iron rods used to hold up the guards.

Cutoff Valve- a valve designed to cut live steam off prior to the piston reaching the end of its stroke.

Cylinder- the heart of a steam engine. Steam expands in the cylinder pushing the piston and moving the paddlewheel.

Cylinder timbers- a long structural member which supported the engine cylinder and paddlewheel shaft.

Deadrise- the upward angle of a floor in a ship's hull.

Death hook- a hook on the end of a safety valve lever where the engineer could hang weights to increase steam pressure.

Deck beam- transversely oriented framing above which decking is affixed.

Depth of hull- in a ship's hull the distance from the bottom of the keel to the underside of the deck beam.

Doctor- auxiliary engine used to pump water to the boilers, or work the bilge pumps or fire hoses.

Draft- the amount of hull extending into the water as measured vertically.

Figurehead- the figure on a ship's bow.

Firebox- the compartment where wood or coal was burned in order to heat the boilers.

Flange- 1. the metal ring surrounding the end of a flue by which it was connected to the boiler head. 2. The hub on a paddlewheel where the arms are attached.

Floors- the bottom most portion of the frames or ribs of a ship.

Flue- an iron tube running through the boiler for the purpose of conveying hot gases and heating the water more rapidly.
Fluvial- produced by the action of a river or stream.

Furnace- the space under the boilers where the fire is built.

Futtocks- the separate pieces of timber which form the frames of a ship.

Garboard- planks directly adjacent to the keel.

Gauge cocks- valves located on the boiler head used for monitoring the water level inside the boiler, also known as try cocks.

Grummet- lead washers used to make boiler joints steam tight.

Guards- portion of the deck that overhangs the side of the vessel.

High-pressure engine- a steam engine powered by the expansive force of high-pressure steam injected into the engine's cylinder.

Hogging- the tendency for a hull to hump up in the center and droop at the ends.

Hogging chain- An iron rod passing over braces used to prevent the hull from hogging or sagging.

Hold- the interior space of a the hull, used for cargo.

Hold streak- longitudinally oriented timbers that run on the tops of the frames (or ribs) of a ship.

Hull- the outer shell of a vessel exclusive of masts, yards, sails, and rigging.

Hurricane deck- the third deck, located above the boiler deck.

Iron circle- the iron reinforcing ring that extends around the diameter of a paddlewheel, just inside the bucket planks, to strengthen the structure.

Keel- longitudinal timber that extends the length of the bottom of the vessel. It forms the backbone of the vessel.
Keel plank- a keel which is the same size or only slightly larger than the garboard planks to either side.

Keelson- an interior longitudinal timber that runs along the centerline of the vessel and rests on top of the frames or ribs.

Key- a blunt wedge used for adjustment of a wooden or metal structure.

Knee- a timber hewn or grown into a right angle to provide strengthening and support at the points of intersection of ship's timbers.

Knuckle chains- an iron rod used to hold up the sides of the hull.

Leeway- the tendency of a sailing vessels to be pushed down wind rather than the desired direction.

Lines- the shape of a hull.

Low pressure engine- an engine type that was powered by a low pressure of steam, the driving force coming from the application a partial vacuum formed in the cylinder.

Main deck- the lowest external deck, the one that covers the hull.

Manhole- an hole in the boiler head through which the boiler can be cleaned or inspected.

Mast- any upright spar.

Model bow- a sharp bow.

Mortice- recess carved into a timber for the purpose of fitting another timber.

Moulded- the height of a timber in the hull of a ship

Mud Drum- a cylindrical container below the boilers used to collect sediment.

Outboard- in a lateral direction from the hull of a ship.

Oxbow Lake- a river bend that has been cut off from the river to form a lake.

Packet Boat- a vessel carrying passengers and freight, equipped for overnight trips.
Pilothouse- uppermost compartment of the steamboat from which the pilot steers the vessel.

Pitman- the connecting rod between the engine crosshead and the paddlewheel crank.

Plans- drawing showing the construction or shape of a vessel.

Planter- a snag that is fixed to the riverbed.

Pocket- recess within a paddlewheel flange is used to secure the paddlewheel arm.

Poling- method used to move a keelboat in which the crewmen set their poles against the river bottom and walk along the edge of the deck from bow to stern.

Quarter deck- that part of the upper deck of a ship which is abaft the mainmast, or approximately where the mainmast would be in the case of those ships without one.

Rockered Keel- a keel that bends upward at the bow and stern.

Room and space- the distance between floors.

Rudder- a hinged plate at the stern of a vessel used to control its direction.

Safety valve- a relief valve which opened when the boiler pressure exceeded a predetermined amount.

Saloon- the large hallway that ran the length of the boiler deck.

Sawyer- a snag whose upper end moved up and down in the water column.

Scantlings- timbers used in ship construction.

Schooner- a type of ocean going vessel rigged principally with fore and aft sails.

Scow bow- a square, raking bow.

Scuttle- to intentionally sink a vessel.

Sheer- the graceful swooping curve of the upper hull when seen from the side.

Sheer strake- uppermost stake in the hull of a ship.

Shoal- shallow water area in a river or other body of water.
Sided- the width of a timber in the hull of a ship.

Sidewheeler- type of steamboat in which the two paddlewheels are located one on each side of the hull.

Snag- a tree in the riverbed forming an obstruction to navigation.

Snag chamber- a sealed chamber within the bow of a boat used to prevent the entire hull from flooding in the event of a rupture by a snag.

Spoonbill bow- type of steamboat bow with full lines.

Stanchion- vertical framing post supporting a deck.

Steam drum- a cross pipe above the boilers used for collecting and distributing steam.

Stem- the forwardmost timber in the hull.

Sternpost- the after most timber in the hull.

Sternwheeler- type of steamboat in which the single paddlewheel is located at the stern.

Superstructure- the decks and structure above the main deck.

Terminus post quem- the date after which an archaeological feature must have been deposited.

Texas deck- the fourth deck, located above the hurricane deck.

Trans-Appalachian West- lands west of the Appalachian Mountains.

Transom- the athwartships timbers bolted to the sternpost of a ship to give her a flat stern.

Turn of the bilge- the portion of the hull where the sides meet the bottom.

Turnbuckle- a slotted casting with threaded holes used to tighten hogging, cross or knuckle chains.

Warping- method used to move a keelboat in which a rope was attached to a fixed point and the vessel was pulled along that rope using a capstan or windlass.

Windlass- a horizontally oriented cylinder on a ship's deck used to pull in lines or cable.
## APPENDIX I

Western River Steamboat Construction and Tonnage, 1811 - 1880

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### APPENDIX II

Table of Steamboat Measurements from 1850  
*(after Walworth, *The Wheeling Bridge Case*, pp. 635-639)*

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<tr>
<th></th>
<th>Bucyrus State</th>
<th>Keystone State</th>
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<th>Brilliant</th>
<th>Cincinnati</th>
<th>Clipper No. 2</th>
<th>Paris</th>
<th>Cinderella</th>
<th>Kezar Newton</th>
<th>Geneva</th>
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<tr>
<td>1 Length of deck</td>
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<td>250</td>
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<td>220</td>
<td>227</td>
<td>235</td>
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<tr>
<td>2 Breadth of beam</td>
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<td>38</td>
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<td>39</td>
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<td>35</td>
<td>40</td>
<td>13</td>
<td>33</td>
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<td>5 Height from water to hurricane deck</td>
<td>27</td>
<td>26.5</td>
<td>26.3</td>
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<tr>
<td>6 Height from water to top of pilot house</td>
<td>46.5</td>
<td>45.5</td>
<td>46</td>
<td>44.5</td>
<td>45.8</td>
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<td>45.5</td>
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<tr>
<td>7 Height from water to hinges of chimneys</td>
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<td>27.5</td>
<td>61</td>
<td>61.3</td>
<td>27.8</td>
<td>54</td>
<td>38</td>
<td>45</td>
<td>46</td>
<td>39.8</td>
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<tr>
<td>8 Height from water to top of chimneys</td>
<td>76</td>
<td>77.5</td>
<td>71.3</td>
<td>71.3</td>
<td>82</td>
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<tr>
<td>9 Height from water to flues</td>
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<td>9.5</td>
<td>9.5</td>
<td>9.5</td>
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<td>10.5</td>
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<td>10</td>
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<tr>
<td>10 Height of chimney from boiler</td>
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<td>67.5</td>
<td>61.8</td>
<td>61.8</td>
<td>71.5</td>
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<td>49</td>
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<tr>
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<td>12 Fire bridge to boilers</td>
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<td>11</td>
<td>10</td>
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<td>Clipper No. 2</td>
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<td>Cinderella</td>
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<td>Area for passage of smoke over bridge</td>
<td>Sq. feet</td>
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<td>20</td>
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<td>12.5</td>
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<td>Grate: height to boilers</td>
<td>in inches</td>
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<td>22</td>
<td>18</td>
<td>18</td>
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<td>in inches</td>
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<td>Cincinnati</td>
<td>Clipper No. 2</td>
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<td>Cinderella</td>
<td>Isaac Newton</td>
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<td>Height from water to top of pilot house (in feet)</td>
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<tr>
<td>Height from water to top of chimneys</td>
<td>in feet</td>
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<td>64.5</td>
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<td>13.5</td>
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<td>Europa</td>
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<td>North River</td>
<td>St. Anthony</td>
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<td>41</td>
<td>Fuel: Wood used in 24 hours</td>
<td>cords</td>
<td>35</td>
<td>31</td>
<td>25</td>
<td>24</td>
<td>36</td>
<td>28</td>
<td>30</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Usual speed upstream</td>
<td>mi. per mi.</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>12</td>
<td>9</td>
<td>10</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Cuts off steam at</td>
<td>$s^2$</td>
<td>1/8</td>
<td>1/8</td>
<td>1/8</td>
<td>1/8</td>
<td>1/8</td>
<td>1/8</td>
<td>1/8</td>
<td>1/8</td>
<td></td>
</tr>
</tbody>
</table>
VITA

Adam Isaac Kane received his Bachelor of Arts degree with honors in Anthropology from Millersville University of Pennsylvania in May 1995. Upon completing his undergraduate studies, Mr. Kane was employed as an archaeological consultant by Cultural Heritage Research Services, at North Wales, Pennsylvania, and then by R. Christopher Goodwin & Associates, Inc. (RCGA), at Frederick, Maryland. At RCGA Mr. Kane served as an archaeological crew chief, a remote sensing specialist, and a scientific diver. From 1997 through 2000, Mr. Kane attended Texas A&M University's Nautical Archaeology Program, where he focused his studies on marine steam technology. Upon completing his course work, Mr. Kane accepted a position as a nautical archaeologist at the Lake Champlain Maritime Museum's Maritime Research Institute. Mr. Kane may be reached at the Lake Champlain Maritime Museum, 4472 Basin Harbor Road, Vergennes, Vermont, 05491.