Boats propelled by paddle wheels and animal propulsion: a curious history

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Abstract. In the eighteenth century, there were three major innovations that produced significant changes to shipbuilding and the ship. This is the advent of iron construction, the use of the alternative steam machine and the invention of propeller propulsion. The incipit of the development of steam propulsion originates in the mechanical transmission of boats with paddle wheels. Already in the Renaissance scholars and inventors of the most diverse fields of knowledge had imagined being able to apply the paddle wheel transmission to the motion of a boat. We find examples of this in manuscript and printed treatises on the most ingenious inventions and projects of the time. However, the real development of the steam engine-propelled ship came when the propeller replaced the paddle wheel, so it is an invention of recent times, perhaps even taken from the technology of windmills. The need to have a driving force able to rotate an endless screw, even if called a propeller-screw, caused numerous well-known or less known authors to experiment in the design of curious boats with wheels formed with blades moved by human or animal propulsion. In this brief note, we want to talk about the development of a naval propulsion system, which, in the pioneering period of the development of steam propulsion, played a not inconsiderable role in the evolution of the paddle wheels transmission.

Keywords. Shipbuilding, propeller propulsion, paddle wheels, animal propulsion, horse boats

1. Introduction

In the eighteenth century, there were three important innovations that produced significant changes in shipbuilding. These are the advent of iron construction, the use of the alternative steam machine and the invention of propeller propulsion. The steamship quickly became the main means of transport used in the nineteenth century to navigate using precisely the energy produced by the steam of a boiler. This innovation started a real revolution in ship propulsion, so much that it determined the gradual disappearance of sailing vessels in little more than a century. The early nineteenth century saw first the major rivers and lakes, then the seas, furrowed by ships moved by this innovative technology that imposed a new shipbuilding development, new boat building techniques, the instruction of workers able to use the new iron and steel materials for the construction of engine apparatuses and boats, a different approach in the use of both merchant and warships, and particular attention to the

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training of crews and entailed a considerable economic and administrative effort by the various western navies.

Within this story, a consequence of the industrial revolution of the eighteenth century, there is a curious story about wheeled boats driven by animal propulsion that spread throughout Europe and America with interesting technological and commercial developments.

2. Wheel and paddle transmission, the archetype of the ship's propeller discovery

The incipit of the development of steam propulsion originates in the mechanical transmission with blades of boats. Already in the Renaissance, the most diverse fields of knowledge scholars and inventors had imagined being able to apply the paddle transmission to the motion of a boat. They are the so-called Renaissance Engineers who, through their intuitions and their propensity to "mechanical" invention, gave impetus to distinct disciplines of mechanics applied to machines, architecture and the art of war. We find examples of this in manuscript and printed treatises on the most ingenious inventions and projects of the time[2]. However, the real development of the steam-propelled ship came when the propeller replaced the paddle wheel: an invention of recent times perhaps taken from windmill technology[3]. The idea of the propeller is certainly due to Leonardo da Vinci (1452 - 1519), even if the Archimedes screw is the archetype of what would later become the propeller, used as a screw in the first submarines. The Prolegomena of the history of the propeller are complex to reconstruct due to the difficulty of finding reliable information. Roger Bacon (1214 - 1294) already imagined that it was possible to sail with a boat moved by an internal "propeller" [4] and reported that he had seen with his own eyes a boat moving on the Thames in London, by means of this new system of locomotion[5].

The need to have a driving force capable of rotating a screw, even if called a propeller, caused numerous known or less known authors to try their hand at designing curious boats with paddle wheels propelled by human or animal propulsion. In a manuscript of the XIV century[6], Guido da Vigevano (c. 1280 - c. 1349) illustrates a boat, perhaps submersible, moved by paddle wheels by means of double-elbow cranks and equipped with floating tanks. In another anonymous manuscript[7], we see a boat with side wheels and cranks that can even be dismantled into four parts, perhaps designed to carry on following the army. Then follow the utopian proposals of Konrad Kyeser (1366 - after 1405) that in his treatise *Bellifortis* (c. 1405), he imagined a boat driven by a system of side wheels[8] where the movement of the wheels, thanks to the strength of man, was transmitted by a crankshaft in the centre of the boat. Even in the collection of "imaginative" machines by Giovanni Fontana (c. 1393 - post-1455) we

[2] Gille, B. *Leonardo e gli ingegneri nel Rinascimento*. Milano: Feltrinelli, 1980.

[3] Forbes, R. J. *Studies in Ancient Technology*. Vol. 2. Leiden: Brill, 1993 (3rd ed.); p. 105.

[4] *Letter on the Secret Workings of Art and Nature …*, published in Bacon, R. (1859), Brewer, J.S. (ed.), *Opera Quaedam Hactenus Inedita*, Vol. I. London: Eyre & Spottiswoode, 1859; p. 533.

[5] Lindsay, W. S. *History of merchant shipping and ancient commerce*. Vol. IV. London: S. Low, Marston, Low, and Searle, 1874; p. 15-16.

[6] *Texaurus regis Francie*, Ms Fond. Lat. n. 11015 f.49r. [Bibliothèque nationale de France, Paris (BnF)].

[7] Ms Palat. 767, f. 134v. [Biblioteca Nazionale Centrale, Firenze (BNCF)].

[8] Manuscript preserved at Bayerische Staatsbibliothek, München (BSB); Ms BSB-Hss Clm 30150, pl. n. 98 and Ms Elsaß (c. 1460) and Ms. germ. qu. 15, f.228 [Goethe Universität, Frankfurt am Main].

see a ship moved by "paddle wheels" [9], as in the work of Jacob Leupold (1674 – 1727) where the boat was driven by the action of the water itself[10]. In *De Re military*, Roberto Valturio (1405 - 1475) imagines a boat moved by five pairs of wheels with paddles moved by a system of cranks connected to each other, with a directional rudder and even proposes a boat made up of removable blocks[11]. Francesco di Giorgio Martini (1439 - 1501) imagined a riverboat[12] powered by a mixed mechanical system made up of paddle and oar wheels[13] set in motion by human strength inside a wheel placed in the centre of the boat, and Leonardo da Vinci[14] shows some sketches related to a boat with paddle wheels and crank mechanisms for the propulsion of boats. The innovative boat proposed by Filippo Brunelleschi (1377 - 1446) called "Badalone" [15], probably belongs to this family of boats, probably used to transport the white Carrara marble necessary for the construction of the dome of the cathedral of Florence.

The Anonymous of the Hussite war (c. 1470-80)[16] described in a drawing a wheeled transmission with a crankshaft, while in *De machinis libri decem* (c. Between 1430 and the 1449), Mariano di Jacopo called the Taccola (1381 - 1453) imagined to make rotate the transmission shaft with the force of the water and with a rope towing system to be able to go up the rivers against the water current[17]. Otherwise, in an anonymous manuscript kept in the British Library we see a man who runs inside a wheel and moves a paddle wheel system; likewise some images of boats moved by paddle wheels are shown in the Code S.IV.5 (f. 55v, f. 56r, f. 64v) which is preserved in the Municipal Library of the Intronati of Siena. Images of complex machines are those proposed by Antonio da Sangallo the young (1484 - 1546) regarding a "Ship with a machine formed by a large wheel on which men walk".

In the seventeenth century, Father Antonio Torelli (1561 - after 1634) described a boat moved by paddle wheels[18] that he experimented in Malta in 1619, managing to reach a speed of 4.5 km/h. His intent was to bring to the Christian cause against the Turks an artifice capable of seeing them victorious in the naval field[19]. Gaspar Schott (1608 - 1666) reports that he saw a wheeled mechanism similar to that proposed by

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[9] Fontana, Johannes de. *Bellicorum instrumentorum liber*. Venedig, c. 1420; Cod.icon. 242, f.38r [BSB].

[10] Leupold, Jakob. *Theatri Machinarum Hydraulicarum II*. Leipzig: Zunkel, T.1/1724, T.II/1725; T. II.

[11] Valturio, R. *De re militari*, Ms. Canon. Class. Lat. 185. Rimini, ante 1462; f.190; Tav. LIX, f.110v. A similar image is attributed to Bonaccorso Ghiberti (1451 - 1516), *Zibaldone*, Banco rari 228, f.216v [BNCF]. See: Bassignana, P.L. (a cura di). *Il necessario e l'immaginario. Le macchine di Roberto Valturio nei documenti dell'Archivio storico AMMA.* Torino: Umberto Allemandi, 1988.

[12] Magliabechiano code II.I.141, p. 188 [BNCF]; Ms. Regg. A46/9-bis (c. 1481-1486) [Biblioteca Panizzi, Reggio Emilia]; Ms. Ashburnham 361, c. 53r [Biblioteca Medicea Laurenziana, Firenze].

[13] *Design for Handle-Propelled Paddle Wheel Boat, and a Hinged Boat in Four Sections. Verso: Designs for War Machines, Pontoon and other* Bridges (1439-1502), ref. 141738v [The Morgan Library & Museum].

[14] The solutions imagined by Leonardo da Vinci are represented in: Codex Atlanticus (f.693r, f.876v, f.945r and f.1063r); Ms B f.83r [Institut de France, Paris]. The same propulsion system is also illustrated in an anonymous drawing preserved in Gabinetto Disegni e Stampe degli Uffizi, Firenze (n. 4085Ar).

[15] Nanni, R. Il Badalone di Filippo Brunelleschi e l'iconografia del «navigium» tra Guido da Vigevano e Leonardo da Vinci, *Annali di Storia di Firenze*, VI. Firenze: University Press, 2011; p. 65-119.

[16] Ms composed during the Ussite Wars (1419-1434), Cod. 3062 HAN MAG; f.472 [Österreichischen Nationalbibliothek, Wien] and Codex Latinus Monacensis 197, f.1r–48v; f.17v [BSB].

[17] Ms. Lat. 7239 (BnF), c. 87r. See: Scaglia, G. *Mariano Taccola. De machinis: the engineering treatise of 1449…* Wiesbaden: Reichert, 1971.

[18] Mabellini, A. Le navi rotate di Fr. Antonio Torelli, *Fanestria. Uomini e cose di Fano*. Fano: Tip. letteraria, 1937; p. 100-122.

[19] *Lettere del Cav.re Antonio Torelli*, Ms 414, f.269 e ss. and f.278r e ss.; f.321; f. 230r; f.6v and 6r.

Antonio da Sangallo[20]. Gaspar Schott himself had imagined a boat that could sail in shallow waters by means of paddle wheels moved by a complex crank mechanism, and again a boat that could even be operated by a single man, thanks to a complex mechanical system.

Among the most curious systems devised by Renaissance scholars and scientists, we mention the six-wheeled ark moved by the animal propulsion of six oxen found in *De Rebus bellicis* (368-369 A.D.), the work of an unknown Latin author[21]. A *Liburna* is also represented in the *Cosmographia Scoti, Notitia dignitatum* ... by an anonymous author, published in Basel in 1436[22]. Similar systems were probably used to move warships, tugs and river passenger ships, in China in the 7th century A.D.[23]. A warship, built in the Song dynasty (960-1279), had 22 paddle wheels, 11 on each side, and it was also equipped with a stern wheel. Propulsion was entrusted to the strength of numerous men[24].

The propulsion of these imaginative boats was entrusted to two substantial types of mechanics: the double crank and elbow system, driven mainly by human propulsion, or otherwise the winch (a capstan) connected to a system of side wheels. These are the prolegomena of a design process that will involve many inventors, scholars, and technicians in the following centuries in search of an economic solution that in the nineteenth century it will saw them engaged in the research of floating machines with paddle wheel propulsion systems, propelled by animals, considering this propulsion system more suitable to carry out the activity in the river and lake area than the "new" steam propulsion.

Even the counter-current towing systems of boats, which exploited the force of water, will be developed starting from the revolutionary ideas of the Renaissance engineers. Indeed, this last propulsion system will find its important application in France in the XVIII and XIX centuries. One of the most famous was the *aquamoteur du Pont Neuf* designed in the 18th century to help boats go up the Seine in Paris, downstream of the islands. The L'*aquamoteur du Pont Neuf*[25] was moored under an arch of the Pont Neuf, and the propulsion to tow the barges to reach the Ile de la Cité was guaranteed by the current of the Seine, which operated its paddle wheels and through a winch and a chain which pull the boats against the water current[26].

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[20] *P. Gasparis Schotti Regiscuriani Societate Jesu, ... Technica Curiosa…* . Norimbergae: Endterus, 1664; Lib. VI, cap. VIII, § III, p. 391-92 and p. 378, p. 386.

[21] Lassandro, Domenico. Note sul De Rebus bellicis, see Sordi, M. *Il pensiero sulla guerra nel mondo antico*. Milano: Vita e Pensiero, 2001; p. 243-51.

[22] *Cosmographia Scoti, Notitia dignitatum … di autore anonimo*, Basel 1436, Ms Canonicianus Misc. 378, f.075v (XV sec.) [Bodleian Library, Oxford]. Fleury, Philippe. La liburne automotrice du De rebus bellicis, Fleury, P., C. Jacquemard et S. Madeleine, *La technologie gréco-romaine: Transmission, restitution et mediation*. Caen: Presses universitaires de Caen, 2015; p. 77-95. Guidonis Pancirolli. *Rerum memorabilium, sive, Deperditarum pars prior*. [Frankfurt]: Sumptibus haeredum Joannis Godefridi..., 1660; p. 127.

[23] Spratt, H.P. The Marine Steam-Engine, in Singer, C.; E.J. Holmyard, A.R. Hall and Trevor I.W. *A History of Technology*, vol. 5 Oxford: Clarendon Press, 1958; p. 142.

[24] Dear, I.C.B. and P. Kemp (ed.). The Oxford Companion to Ships and the Sea. Oxford: University Press, 2006. Needham, J. *Science and Civilisation in China*, Vol. 4: Physics and Physical Technology; Part 2: Mechanical Engineering. Cambridge: University Press: 1971; p. 431.

[25] L'Aquamoteur du Pont Neuf is illustrated in *Encyclopédie ou Dictionnaire raisonné des sciences, des arts et des métiers*, Tomo II. Paris: 1763, Pl. XXXIX bis, XL, XLI.

[26] Coste, L.M.-P. Théorie des aquamoteurs ou des bateau mus par la courant de l'eau, *Journal du Génie Civil des Sciences et des Arts*, Tome XIV. Paris: 1846; p. 1-19.

In 1543, Blasco de Garay (1500 - 1552) designed a motor to move a vessel using the principle of the aeolipile of Heron of Alexandria (I-III century A.D.) [27]. Subsequently, the Catalan inventor succeeded in making a boat navigate with a propeller to shovels moved by the action of four or more men[28]. Some years later, in 1578, William Bourne (1535 - 1582) proposed to build a boat operated by means of wheels placed on the sides of the boat itself[29]. Also Fausto Veranzio (1551 - 1617) studied the possibility of moving a boat by means of paddle wheels and he published his idea in the *Machinae Novae* treaty[30].

These were years of great experimental fervour and several patents were registered in England in the first half of the seventeenth century and numerous inventions of boat propulsion systems were published. In 1618, and then again in 1630, David Ramseye or Ramsay (? - c. 1653) patented a method to allow boats and barges to sail upstream [31]. Other patents relating to the propulsion of boats with rather rudimentary methods were registered by inventors and experimenters such as Thomas Grant (? - 1649) in 1632, Francis Lin (c. XVII century) in 1637 - together with Henry Yorke (c. XVII century) and Francis Myles[32] (c. XVII century) - and Edward Ford (1605 - 1670) in 1640[33]. Thomas Grant (c. XVII century) obtained also a privilege from Charles of England [Carlo I Stuart (1600 - 1649)] for a new boat propulsion system that allowed them to navigate even against the water current and also in case of a calm, he called it *Winds Mate* or *Maty*[34]. Thomas Togood or Toogood (c. XVII century) and James Hayes (c. XVII century) in 1661 proposed a method of propulsion which foresaw to force the water out of the stern of a ship by means of a bellows[35] and in 1663 Edward Somerset (c. 1602 - 1667) published a curious collection of his inventions[36] among which there is a device to raise water by means of steam and another is a kind of ship capable of going up the current of a river, exploiting the force of the current flow for the propulsion of the ship[37].

The idea of using the wheels of windmills was a revival of design solutions "invented" by the Renaissance engineers and it is part of a scientific imaginary, which was certainly typical of a mechanistic culture developing in those years. In fact, Mechanisms designed along the lines of windmill blades were designed by John Oldham (1779 - 1840), taking up the ideas of Robert Hooke (1635 - 1703), and by William Emerson (1701 - 1782)[38].

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[27] Seaton, A.E. *The Screw Propeller: And Other Competing Instruments for Marine Propulsion.* London: Charles Griffin, 1909; p. 3.

[28] Spratt, H.P. *The Birth of the Steamboat*, London: Griffin, 1958 and Spratt, H. P. The Prenatal History of the Steamboat, *Newcomen Transactions*, Vol. 30, 1955–7.

[29] Bourne, W. *Inventions or Devises, … .* London: Thomas Woodcock, 1578; The 19. Devise; p. 15.

[30] Veranzio, Fausto. *Machinae Novae* (Venetiis, 1616), Pl. n. 40.

[31] Woodcroft, B. *A Sketch of the Origin and Progress of Steam Navigation from Authentic Documents*. London: Taylor, Walton, and Maberly, 1848; p. 3-4.

[32] *Ibidem*; p. 122.

[33] Lindsay, W.S. *History of Merchant Shipping … .* Cambridge: University Press, 2013; p. 17.

[34] Rymer, T.; Sanderson, R.; Holmes, G.; Clarke, A.; Holbrooke, F. *Foedera, conventiones, literae et cujuscunque generis acta publica, … .* Vol. 8. Hagae Comitis: Joannem Neaulme, 1743; p. 233.

[35] Woodcroft, B. *Op. cit.*; p. 7 and Bourne, J. *A Treatise on the Screw Propeller*. London: Longman, Brown, Green and Longmans, 1855; p. 3.

[36] *A century of the names and scantlings… .* London: J. Grismond, 1663.

[37] *Ibidem*; p. 41-42. Bourne, J. *Op. cit.*; p. 3 and Thurston, R.H. *A history of the growth of the steam-engine*. New York: D. Appleton and company, 1886; p. 21.

[38] Emerson, W. *The principles of mechanics*. London: G. Robinson, 1773 (3rd ed.); Pl. XII, fig. 203.

3. The birth of animal propulsion *vs* steam propulsion

The first studies on steam propulsion date back to the researches of Salomon de Caus (1576 - 1626) who seems to have experienced, as early as 1615, a system to produce steam[39] and to Hooke's studies; he had imagined to use a wheel to move a boat[40], using a propulsion system similar to windmills mechanism[41]. At the end of the century, Thomas Savery (1650 - 1715) patented a first steam engine and he illustrated it to the Royal Society, and the following year (1699) he built a boiler system without pistons, which exploited the pressure of compressed and atmospheric steam alternately. He had imagined that this invention could also be applied to naval propulsion[42]. In 1730, John Allen (1660? - 1741) proposed to move a boat by means of a hydraulic system which consisted of a mechanism to pump water to the bow and expel it from the stern, and he suggested the use of steam propulsion to achieve this purpose[43]. Jonathan Hulls (1699 - 1758) designed the first steam tugboat in 1736[44]. The tug had to be moved by two pairs of wheels, one connected to the engine apparatus and one external to the stern of the boat, the latter equipped with shaped blades oars that had to help push the boat. The discovery of the steam engine, which gives movement to a paddle wheel mechanism, will become so over the next years the first effectively functional propulsion system, thanks to the improvements obtained by James Watt (1736 - 1819) with the realization of his steam engine, developed in the years 1763-1775[45].

In these years where the pioneers of mechanics and new energy sources experimented with new inventions, together with the development of the first steamboats, other alternative forms of propulsion were also sought. One of these was the propulsion provided by animals, especially horses, where, however, the boat was not towed by animals along the shore - as was the case for towing boats along the canals - but the oxen or horses operated a mechanism of wheel propulsion directly placed on the boat. However, it was not the fanciful "inventions" of the engineers and scholars of the Renaissance; the industrial revolution and the machine revolution had provided inventors and experimenters with new mechanisms and new types of machinery that made possible what was once no more than an imaginative idea. No longer being tied to the whims of the wind or the force of the currents, and also with the intent to reduce the use of human muscular force to move the rowing ships, researchers were certainly oriented to develop this different naval propulsion system. In 1682, a boat moved by wheels placed on the sides of the hull and where the energy was supplied by four, six or eight horses - *A horse* "*tow-vessel*" - was tested at Chatham, and used as a tugboat[46]. Perhaps the first real boat propelled by animal propulsion[47]. In

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[39] Salomon de Caus. *La raison des forces mouvantes*. Paris: Hierosme Droüart, 1624; p. 4r and Dollar, R. *130 years of steam navigation*. San Francisco: Schwabacher-Frey Company, 1931; p. 1.

[40] Hooke, R. *Philosophical Collections,...* London: J. Martyn & R. Criswel, 1679-1682; Pl. 8, p. 63.

[41] *Ibidem*; p. 61-64.

[42] Savery, Thomas. *Navigation Improv'd, ...* . London: James Moxon, 1698 (Pl. p. 8).

[43] Allen, J. *Specimina ichnographica.* London: W. Inny, MDCCXXX. (1730).

[44] *The Repertory of Patent Inventions, and Other Discoveries and Improvements in Arts, Manufactures, and Agriculture...* G. and T. Wilkie, 1831; p. 247-252. Hulls, J. *A description and draught of a new-invented machine for carrying vessels or ships ...* . London: Printed for the author, 1737. Westcott, T. *The Life of John Fitch. The Inventor of the Steamboat*. Philadelphia: J.B. Lippincott & Co., 1857; p. 375.

[45] Dickinson, H. W. *A Short History of the Steam Engine*. Cambridge: University Press, 1939.

[46] *A horse "tow-vessel".* Stuart, R. *Historical and Descriptive Anecdotes of Steam-engines, and of Their Inventors and Improvers*, Vol. 1. London: Wightman and Cramp, 1829; p. 98. Spratt, H. P. The Marine Steam-Engine, Singer, C.; E. J. Holmyard, A.R. Hall and T.I. Williams. *A History of Technology*, vol. 5 Oxford: Clarendon Press, 1958; p. 149.

the 17th century, the Palatine Count of Reno Rupert (1619 - 1682) built a ship moved by horses to tow His Majesty's ships on the Thames[48]. Unfortunately, this propulsion system turned out to be not entirely suitable[49]. In 1722 Drouët (c. XVIII century) proposed a "Machine pour remonter le bateaux", a boat equipped with five drums overboard equipped with paddle wheels like those of the mills, moved by the current of the river[50]. Along the lines of Drouët's project, in the same series of *Machines et inventions approuvées par l'Académie royale des sciences*[51], it is possible to read descriptions of the inventions proposed by scholars, inventors, engineers of the eighteenth century little known but of undoubted planning abilities such as Martenot, Du Quet, Lavier, Chabert, Boulogne, Caron and Duvivier. They designed boats capable of navigating even against the current by exploiting various and curious water propulsion systems. De Graville (c. XVII century) proposed a propulsion system that made it possible to go back up the current by exploiting its energy. We have news of this from the treaty attributed to Bouillet (c. XVII-XVIII century), which mentions the experimentation of this boat, loaded with salt, on the Rhine in Lyon in 1690[52].

A century later (1732) the Maréchal de Saxe (1696 - 1750) proposed two different systems for moving a boat[53]. From two to four horses provided the propulsive force to turn the gear wheel of the capstan (winch) equipped with a series of radial bars to which the horses were harnessed: in the first case the winch was connected to a rope anchored to the ground which it wraps around an axis and the boat was thus towed against the current; in the second case the winch is connected to a transmission shaft which set in motion two bladed wheels placed laterally to the hull. The speed of the boat was of a league (c. 4,828 m) an hour against the current and two leagues per hour in favour of current[54].

In 1785 Claude-Simon de Mandres or Demandre (1728 - 1803) obtained the privilege from the Assemblée Nationale for the construction of a boat called "levier-moteur" [55] of his invention and two years later (29 and 30 December 1787) he made first official experiences in Strasbourg. It was a boat with a platform on which was placed a capstan and a central wheel driven by twenty men, who set in motion two wheels with paddles placed on each side of the boat. In the case of very strong currents, a rope of around 440 meters was also used, fixed to the shore and wound around the

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[47] *Annales de l'Industrie nationale et étrangère, ...* Tome Huitième. Paris: Bachelier, 1822; p. 294.

[48] Jones, Thomas P. (ed.). *The Franklin Journal and American Mechanics' Magazine*, Vol. 4. Philadelphia: Judah Dobson, 1827; p. 207.

[49] Erickson, H.H. History of horse whims, teamboats, treadwheels, and treadmiIls, Equine Exercise Physiology 7, *Equine vet. J., Suppl.* 36 (2006), p. 83-87.

[50] *Machines et inventions approuvées par l'Académie royale des sciences depuis son établissement... (jusqu'en 1754) avec leur description.* Tome Quatrième. Paris: G. Martin, J.-B. Coignard Fils, H.-L. Guerin, 1735; p. 43-44.

[51] *Ibidem.* Tome Second; p. 25-26; p. 31-33; Tome Second; p. 141; pp. 177-79; Tome Quatrième; p. 203-08 and 209-12; p. 213-16; Tome Cinquième, p. 95-96; Tome Sixième; p. 195-96.

[52] [Bouillet]. *Traité des moyens de rendre les rivieres navigables...* Paris: Estienne Michallet, 1693; p. 89-93. *Ibidem*; p. 89 e Pl. 11, fig. 3, p. 92.

[53] *Machines et inventions approuvées par l'Académie royale des sciences depuis son établissement... (jusqu'en 1754) avec leur description.* Tome Sixième. Paris: G. Martin, J.-B. Coignard Fils, H.-L. Guerin, 1735; p. 37-39 and 41-43.

[54] *Ibidem*; pp. 195-96. First proposal: pl. 1 and pl. 2, p. 40; second proposal: pl. 1 e pl. 2, p. 44 and Faliu, O. *Machines à rêver. Recueil d'inventions XVIe-XIXe siècle.* Paris: Albin Michel, 1985, p. 39-40.

[55] *Pétition à l'Assemblée nationale, par Claude-Simon de Mandres, ... du 18 décembre 1791*. Paris: Imprimerie Nationale, 1791 and de Mandres, Claude-Simon. *Prospectus du Levier-Moteur ou cri(cq)-élliptique de l'Abbé de Mandres…* . Strasbourg: Jean Henri Heitz, 1788. *Précis des Pièces de l'Abbé de Mandres, Relativement à sa découverte, et aux avantages qui en résultent*. Paris: Imprimerie Nationale, 1790.

capstan's drum. In this way, he was able to reassemble the Rhine river, from Wantzenau to the confluence of the great and small Rhine in just twelve hours[56]. Likewise, Patrick Miller (1731 - 1815) built two- and three-hulled boats (the *Edinburgh* trimaran) with paddlewheels driven by human strength and experimented on the Forth River in 1786. Thirty men on the capstan were able to push the boat at a speed of 4.3 knots[57].

In 1802 Johann Friedric Heinle (1753 - 1815) proposed to build a movement device for a boat by means of a "levier-moteur" mechanism he invented[58]. Some years later, in 1817 (April 22), Louis-Alexandre-Désiré Hoyau (between 1775 and 1825) applied for a patent for a "Bateau à manège mu par des chevaux" [59]. The capstan imagined by Hoyau could be operated by two, four, five, six, seven, eight, nine or ten horses which operated two wheels placed on the sides of the boat that could indifferently rotate in the two directions of travel. Moreover, a mechanical system of his invention made the two wheels independent of one another, thus allowing different motions in the boat, linear and rotational. Moreover, its mechanism was equipped with a clutch that was used to stop the movement of the carousel without stopping the horses, and it was a safety device to stop the boat. Finally, the author exposed an inclined plate system that envisaged the motion of the animal on a wheel which was supposed to transmit motion to the side blades[60].

The prototype invented by Ambroise-Théodore Tourasse (17 .. - 18 ..) and Jean-Louis-Nicolas Courteaut (c. XVIII-XIX century) is better known. On January 5, 1819, the two French inventors deposited the patent application[61] for a flat-bottomed boat 23 meters long and 5.20 meters wide, with a central "carousel" mechanism having a diameter of 8.9 meters[62], connected to a tow rope anchored to the shore. The propulsion was entrusted to the force of six horses which, according to the designers, had to guarantee variable speeds from 320 to 1,900 m / h. This tug was able to tow 68 boats from the port of Ainay to the port of Serin, on the Saône in Lyon from 15 November to 26 December 1821[63].

Other similar inventions were proposed in 1821 by Pierre-Alexandre Guilbaud (c. 1786 -?); in this project the animal moved on an inclined plane[64], taking up an idea

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[56] Reuss, Rodolphe. L'Abbé de Mandres et la navigation du Rhin (1788), *Revue d'Alsace et de Lorraine*, 1920, p. 605-606 e *Biographies Universelles (Michaud)*. Tome Dixième. Paris: C. Desplaces, 1855; p. 361-62.

[57] Descombes, R. *Chevaux et gens de l'eau: sur les chemins de halage*. S.l.: Editions Cheminements, 2007; p. 232-34 and Moss, Michael S. Voce: "Miller, Patrick (1731 – 1815)", *Oxford Dictionary of National Biography*. Oxford University Press, 2004.

[58] Descombes, R. *Ibidem*; p. 234 e p. 237.

[59] Patent n. 1BA1045 [Archives Institut national de la propriété industrielle (INPI)]. *Description des machines et procédés spécifiés dans les brevets d'invention de perfectionnement et d'importation dont la durée est expirée…* . Tome XIII. Paris: Madame Hazard. 1827; p. 269-274.

[60] *Ibidem*; Pl. 25, fig. 7.

[61] Combe, J.-M.; Escudié, B.; Payen, J. *Vapeurs sur le Rhône: histoire scientifique et technique de la navigation à vapeur de Lyon à la mer*. Lyon: Presses Universitaires Lyon, 1991; p. 23-24.

[62] Le Normand, L.-Séb. Et J.-G.-V. De Moléon. *Annales de l'industrie nationale et étrangère, ou Mercure technologique…* . Vol. 13. Paris: Bachelier, 1824; p. 35-47, Pl. 151, 152 and 155; Vol. 14. Paris: Bachelier, 1824; p. 51-53.

[63] Tourasse, A.-T. & F. N. Mellet. *Essai sur les bateaux à vapeur appliqué à la navigation intérieure et maritime de l'Europe, …* . Paris: Malher et Cie, 1828-1829; p. 235.

[64] *Procès Verbal de la Séance Public de la Société académique du Département de la Loire-Inférieure, tenue le 19 décembre 1822*. Nantes: Mellinet-Malassis. 1823; p. 54-55.

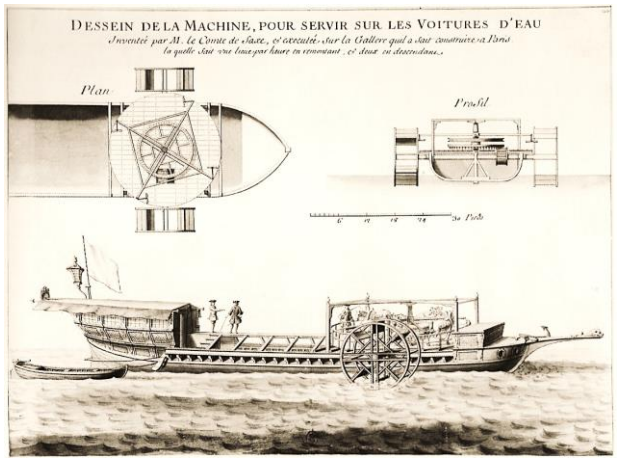


Figure 1. «Dessein de la Machine, pour servir sur les voitures d'eau. Inventée par M. le Comte de Saxe, …» [Ic, 49 (XVIII sec.): Cabinet de Estampes, BnF].

already developed by Giuseppe Antonio Borgnis (1781 - 1863)[65] and the Author also illustrated three distinct animal-propelled boats[66]. Guilbaud made some prototypes that were tested on the Loire and on the Erdre[67] river, with satisfactory results both in terms of speed and fatigue of the animals[68]. In November 1821 the Guilbaud boat, called *Mercure*[69] and equipped with a horse stable, started a regular activity on the Erdre between Nantes and Nort (Nort-sur-Erdre), for a journey of about 30 km. The boats of Guilbaud performed regular service until 1833 when they were replaced by steamboats[70]. The speed of these vessels was modest but sufficient to guarantee a regular river service. On June 21, 1823, Guilbaud climbed the Loire to the Orléans canal and the Loing canal to the Seine, reaching Paris on July 25th[71].

Guilbaud's project for a "Bateau zoolique" tugboat with an inclined work plane of about 30 degrees, it was a large boat about twenty meters long and three meters wide, with a draft of just over 40 cm. The propulsion system was given by two pairs of paddle wheels, one in the bow and one in the stern, set in motion by the force of two groups of three horses moving on an inclined plane. Another "Bateau zoolique" of Guilbaud was used for passenger transport and the propulsion was entrusted to only two horses that worked on a treadmill. A project similar to that of Guibauld was developed by Tourasse and Courteaut: in this case, the central platform moved by rotating horses is wrapping a tow cable placed on a circular drum, similar to that

[65] Borgnis, G. A. *Traité complet de mécanique appliquée aux arts…* . Paris: Bachelier, 1818; Vol. 1, p. 28-31 and Pl. 2. *Bulletin de la Société d'encouragement pour l'industrie nationale, Vingt-unième Année*, Juillet 1822. Paris: Madame Huzard, 1822; p. 203-211.

[66] *Description des Machines et Procédés spécifiés dans les brevets d'invention, de perfectionnement et d'importation, dont la durée est expiré.* Vol. 14. Paris: Madame Huzard, 1827; p. 252-59 (see p. 252).

[67] *Bulletin de la Société d'encouragement pour l'industrie nationale*. 21ème année (N. CCXVII), Juillet 1822. Paris: de l'imprimerie de Me Huzard, 1822; p. 203-207 e 207-210.

[68] *Ibidem*, p. 204-11; *Procès verbal de la Séance publique de la Société académique du département de la Loire-Inférieure tenue le 19 décembre 1822.* Nantes: Mellinet-Malassis, 1823, p. 54-55.

[69] *Feuille commerciale, d'affiches, annonces judiciaires et avis divers* del 2 Avril 1825 (N. 92), p. II.

[70] *Annales Société Royale académique de Nantes et de la Loire-Inférieure de 1833*. Quatrième volume. de l'imprimerie de Mellinet. 1833; p. 474-75.

[71] *Bulletin de la Société d'encouragement pour l'industrie nationale*. 22ème année (N. CCXXIX), Juillet 1823. Paris: de l'imprimerie de Me Huzard, 1823; p. 183-185.

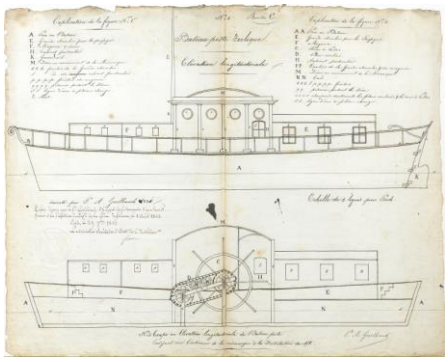
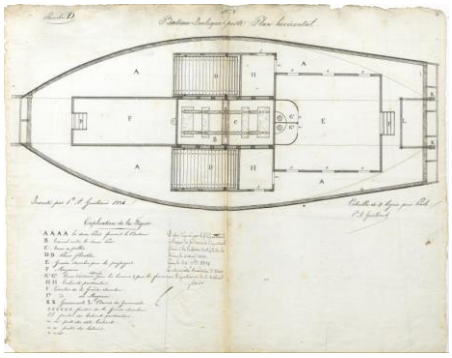
a)  b) 

Figure 2. Guilbaud's postal boat, with central wheel and movement of the horses on an inclined plane. Inside there was a central hall and two separate toilets for men and women, there was also a warehouse for the supply of horses.

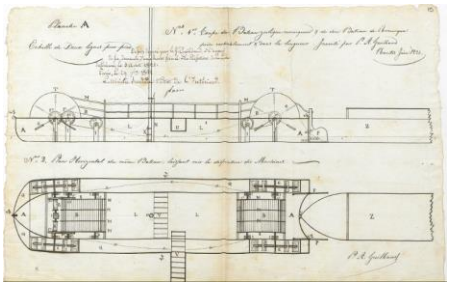
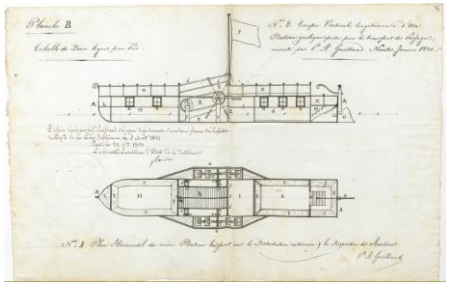
a)  b) 

Figure 3. a) Project for a tugboat, fitted with a towbar at the stern; b) second version of the Guilbaud boat with two lateral-bladed wheels set in motion by an inclined plane driven by two horses acting on a treadmill.

proposed by the Maréchal de Saxe[72]. *Le Rougaillou* was instead a boat driven by a 'ride' of six/eight horses and was used on the Saint-Quentin canal from 1863 to 1874 to tow the barges loaded with goods along the canal.

The success of the equine propulsion boats had a discreet use in France, but a modest diffusion in the rest of Europe, also because the rivers had a width of the modest river-bed and bridges could be easily built to cross them. In order to manage the river transport to Cubzac, on the Dordogne river, on the route from Paris to Bordeaux, Edward Church Jr. (1787 - 1843) built in 1822 a "Bateau à manège"[73], a catamaran called *Saint-Louis*, with a central platform about 24.4 meters long and about 12.2 meters wide, it was very robust and able to carry heavy loads and bulky carriages[74], where 12 horses secured the motion by rotating a capstan connected by a cascade of gears to a wheel placed between the two hulls[75].

One of the strangest "bateau à manège" sailed in Italy on Lake Garda: the *Amico a Prora*, better known as the *Manubrio*. The *Amico a Prora* was a large boat with two

[72] Combe, J.-M.; Escudié, B.; Payen, J. *Op. cit.*; p. 23-31.

[73] Bernadau, Pierre. *Tablettes manuscrites. Faits Divers à Bordeaux entre 1787 et 1852* [Bibliothèque Municipale de Bordeaux, microfilms MIC 1698/5 à MIC 1698/12]. Colle, Michel. *Bernadau, le Grincheux de Bordeaux*. Bordeaux: Les Dossiers d'Aquitaine, 2016.

[74] *Bulletin des sciences technologiques. Cinquième section du Bulletin universel des sciences et de l'industrie*. Tome deuxième. Paris: Bureau du Bullettin, 1824; p. 180-181.

[75] *Actes de l'Académie nationale des sciences, belles-lettres et arts de Bordeaux*. 3e série, 38e volume 1876. 1ere Trimestre, par Jules de Gères. Paris: E. Dentu, 1877; p. 170.

masts and two paddle wheels, with a capacity of 1,000 quintals. These paddle wheels had the particularity of being put into action by eight horses through a gear mechanism. The boat was launched in 1829 in Riva del Garda and carried out its passenger and postal service regularly until 1839. Given the type of horse propulsion (guaranteed by the eight embarked horses which thanks to leather straps were giving the motion of the side wheels) and sailing the boat was considered safe, there was no risk of explosion or fire, so a flag hoisted on the mainmast bore the inscription "La Sicurezza/The Safety"[76]. Where, instead, the bateau-manège was more successful on Lake Geneva[77]. Before the construction of the Pont du Mont-Blanc, from Eaux-Vives to Pâquis (two districts of Geneva), it was necessary to take the "bateau manège": a catamaran about 21 meters long and almost 8 meters wide, with a large platform floating, moved by the strength of four horses that circled around a vertical axis that operated the paddle wheel placed between the two hulls.

4. Horse ferries and Horse boats in America

On the other hand, in North America[78], the "Horse-ferry" or "Horse boats" or "Team-boat" had greater success, as they saw widespread use in small river communities due to their low operating costs compared to steamboats. The team-boats were very large boats driven by the animal propulsion of horses or mules. In general they were of two types: the first with a central carousel where the animals rotated a capstan which transmitted motion to the paddle wheels placed laterally to the boat; the second type used a more complex mechanical system which, through a treadmill and a cascade gear system, allowed the transmission of motion to the wheels but the horse exerted its traction force moving in the direction of the boat's direction of travel. It is believed that the first idea of building a boat powered by equine propulsion was formulated by John Fitch (1743 - 1798) in 1787[79]. In 1791, Henry Voigth (1738 - 1814) patented an animal-propelled boat with the same principle as Fitch's "duck leg" shovels. The monopoly obtained in 1807 by Robert Fulton (1765 - 1815) and Robert R. Livingston (1746 - 1813) relating to the management of steam navigation on the Hudson in New York directed the experimentation to the design a new type of horse boats. In 1814 John Stevens (1749 - 1838) decided to build a trimaran with equine propulsion to connect Manhattan to Hoboken, similar to the boat of Moses Rogers (1780 - 1821). The Rogers' ferry, which connected Catherine Street and Brooklyn, consisted of three hulls of equal length and width with two paddle wheels interposed and driven by 2, 4 or 8 horses or mules[80]. Rogers' boat gave excellent results; in fact, it was able to carry up to 300 passengers on a 1.2 km section travelled in just 7 minutes[81].

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[76] Arseni, A. La navigazione a vapore e i servizi postali sui laghi italiani, *The Postal Gazette*, Numero 1 / Anno IV / Gennaio-Febbraio 2009; p. 34-35.

[77] *Recueil authentique des lois et actes du Gouvernement de la République et Canton de Genève*. Tome XI. Année 1825. Genève: de l'Imprimerie de G.me Fick, 1825; p. 89-97.

[78] Crisman, K.J. e A.B. Cohn. *When Horses Walked on Water. Horse-powered Ferries in Nineteenth-Century America*. Washington & London: Smithsonian Institution Press, 1988.

[79] Sutcliffe, A.J. *Steam: The Untold Story of America's First Great Invention*. New York: Palgrave Macmillan. 2004; p. 123. Shomette, Donald G. Heyday of the Horse Ferry, *National Geographic Magazine*. Vol. 176, No. 4 (10/1989), p. 549–556.

[80] Adams, A.G. *The Hudson Through the Years*. New York: Fordham University Press, 2003; p. 51-52.

[81] Niles, H. Editor. *The Weekly Register, From March to September, 1814 -Vol VI*. N. 9 of Vol. VI, Baltimore, Saturday, April 30. 1814. Baltimore: printed and published by the editor; p. 152.

These boats could be single-hulled, double-hulled or triple-hulled, with propulsion on a winch at the centre of a platform on which the horses operated, or treadmills on which horses were operating in adequate numbers to develop sufficient power to move the horse boat. In catamaran boats, the wheel or the coupled wheels were placed between the two hulls. In the case where treadmills were used, these were placed on both sides of the boat, and in general three horses operated on them. To reverse the direction of the boat it was only necessary to stop the horses for a few minutes and remove a release pin which had the function of reversing the movement of the treadmill. This type of boat had an important economic aspect related to their management; in fact, a steamboat cost around $ 30,000 while a horse-drawn ferry, including the costs of the boat, horses and stable on the ground, cost about $ 12,000. The savings were therefore significant and the speed of these boats was comparable to that of similar steamboats[82]. Furthermore, these equine-propelled barges, not being driven by a steam engine, were not obliged to pay royalties to Fulton and Livingston, who had the monopoly of steam transport on the Hudson and therefore could compete with the new steam-boats.

Also in France, Jean-Baptiste Marestier (1781 - 1812) had proposed a double-hull animal-propelled boat. His boat was 24 meters long, 12 meters wide, and each hull was three meters wide and the distance between them was 3.3 m. The wheel had a diameter of 3.6 meters with eight blades 1.2 meters long and 0.6 meters wide. The ferry deck had a central structure with two compartments, one in the front and one in the rear, presumably to accommodate passengers and a circular shelter in the centre for animals and machinery. A double paddle wheel, with a toothed wheel at the centre for the transmission of the motion, was located between the two hulls. By means of a lever, the direction of rotation of the mechanism and the direction of the movement are reversed but above all the direction of rotation of the motion of the horses. The boat had undifferentiated bow and stern, so it was bi-directional and therefore it was not necessary to do course reversal manoeuvres, for this it was equipped with two rudders, with two distinct manoeuvring winches[83].

The alternative to the platform system was proposed by James B. Robinson (c. 1770 -) in 1816 (Inclined horse wheel), by Moses Isaacs (c. XVIII-XIX century) and John Wilbanks (c. XVIII-XIX century) in 1817 (Wheel horizontal inclined), and then in 1818 (Propelling boats) and in 1819 (Horse wheel)[84]. Their invention consisted of an oblique "chain" placed under the track covered by the horse. Barnabas Langdon (c. XVIII-XIX century) proposed the following year instead a horizontal wheel system[85] placed under the bridge of the boat so that the horses made to turn the wheel remaining lodged in appropriate lateral niches and thus clearing the main bridge from the complex machinery, and also being able to house this propulsion system in a single-hull boat.

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[82] Perkins, Sid. When Horses Really Walked On Water, *The Chronicle of the Horse* (5/1999), p. 90-92.

[83] Marestier, J.-B. *Mémoire sur Les Bateaux à Vapeur des États-Unis d'Amérique* ... . 1 Vol. et 1 vol. planches. Paris: Imprimerie Royale, 1824. See: Vol. 1, p. 78 e Pl. IV, fig. 12, 13, 14.

[84] Crisman, K.J. e A.B. Corn. *Op. cit.*; Elliot, William. *A List of Patents Granted by the United States, for the Encouragement of Arts and Sciences, Alphabetically Arranged from 1790 to 1820*. Washington: S[eth] Alfred Elliot, 1823; p. 27 (Robinson e Isaacs), p. 40 (Isaacs), p. 63 (Wilbanks).

[85] Ellsworth, Henry-Leavitt. *A Digest of Patents, Issued by the United States from 1790 to January 1, 1839 ... To which is Added the Present Law Relating to Patents*. Washington: Peter Force, 1840; p. 561.

An inclined treadmill system was proposed by William Burk (c. XVIII-XIX century) in 1835 and by Rufus M. Porter (1792 - 1884) in 1842[86].

The Experiment (horse paddle-boat), built in 1792 by David (Varnum) Wilkinson (1771 - 1852)[87] was a small boat - with a tonnage of 12 tons - about 15-18 meters long and wide from 4.88 meters to 6.10 meters, about 90 centimetres deep from the plane of the horizontal wheel to the keelson, and was moved by the equine driving force (eight horses) acting on a treadmill. A mechanical system transmitted motion from the horizontal wheel to two shafts which ran along with the boat beyond the stern and rotated two 90-centimetre goose-bladed propellers ("goose-food paddle")[88] instead of wheel blades acting on the water surface. This boat reached the speed of 4 knots per hour, with the help of tide and favourable wind[89].

At the beginning of the nineteenth century, many entrepreneurs imagined launching river communication lines travelled by team-boats. Numerous boats were built but not all experiences were successful: the *Horse Boat*, a barge of about 40 tons, carried out an adventurous journey from New-Orleans to Louisville. In 1820 the *Genius of Georgia* catamaran, an impressive boat about 26 meters long, about 16.8 meters wide and equipped with a 12.2-meter diameter capstan, moved by a force of 24 horses, it was used along the Savannah River[90]. However, the effort required of the animals was still too important for long-term service and some companies turned out to be a commercial failure.

The river transport with animal-propelled boats turned out to be effective for ferrying people and things between the two sides of a river. A short and non-continuous journey was the best solution, not excessively tiring the animals (often blind horses were used for this job), and it proved to be competitive with steamers due to the reduced operating cost.

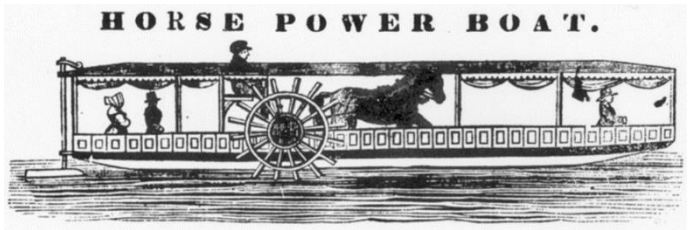

Figure 4. Horse Power Boat di Rufus Porter, in *American Mechanic*, Vol. 2, no. 37 (24 September 1842), p. 1[91].

[86] Horse Power Boat, *American Mechanic*, Vol. 2, no. 37 (24 September 1842), p. 1 e *Transactions of the Rhode Island Society for the Encouragement of Domestic Industry*. Providence: Knowles, Anthony & Co., 1859; p. 31.

[87] Van Wyk, Eugene. William Hamlin: Providence Engraver, *Rhode Island History*, Vol. 20, n. 2 (April 1961); p. 36. See *Transactions of the Rhode Island Society for the Encouragement of Domestic Industry in the year 1858*. Providence: Knowles, Anthony and Co., State Printers. 1859; p. 31-33.

[88] Field, Edward. *State of Rhode Island and Providence Plantations at the end of the century: a history*. Vol. 2. Boston: Mason Publishing Company, 1902; p. 510.

[89] *Transactions of the Rhode Island Society … Op. cit.*; p. 31-33.

[90] Phillips, Ulrich Bonnell. *A History of transportation in the Eastern cotton belt to 1860*. New York: The Columbia University Press, 1908; p. 74.

[91] Erickson, H.H. History of horse-whims, teamboats, treadwheels and treadmiIls. *Equine Veterinary Journal*, 38 (S36), 2006; p. 83-87; fig. p. 23.

These boats were very popular in the United States in the first half of the nineteenth century (1810-1850)[92] and in Canada. The first Canadian horse-propelled vessel was built in Toronto by brothers Louis Joseph (1817 - post 1893) and Peter Louis Privat (1799 - 1860) in 1843 and it was called *Peninsula Packet*, it was powered by two horses, each of which walked on a treadmill, which operated two wheels with side blades, long c. 18.30 m and wide c. 6.70 m[93]. There are reports of animal-powered boats between Halifax, Nova Scotia, and Dartmouth, on the St. Lawrence River, between Québec and Lévis and between Ottawa and Pointe-Gatineau. The most famous horse boat of Montreal was the *Edmond*, in service between Montréal and Longueil; built in 1819 by François (Jérémie) Denaut (c. XVII-XIX century) it was driven by the force of 10 horses[94]. The 'Union Team Boat' performed regular services from Georgetown to Alexandria in Virginia and again on the Ohio River in Cincinnati and on the Ashley River in Charleston, South Carolina; in Camden, New Jersey, on the Delaware River operated numerous horse-propelled ferries: *Washington*, *Phoenix*, *Constitution*, *Moses Lancaster*, and *Independence*, although numerous steamboats were already in service in the same locality[95]. On Lake Champlain, bordering the states of New York and Vermont, team-boats were used until the mid-19th century. The first horse boat that operated on Lake Champlain was called *Experiment* and it served between Port Henry, New York and Chimney Point, Vermont in 1826. Another larger ferry was the *Eclipse* - entered service in 1828 - the largest and most famous of his time was 20.7 meters long and 7.6 meters wide. It connected Charlotte to Essex Village and travelled a distance of 4.8 km in about 30 minutes thanks to the propulsion of six horses. The *Eagle* secured the link between Basin Harbour and Westport, 5.6 km away, driven by the force of only two horses and remained in service until 1844. The first team boat that sailed on Lake Winnipesaukee (New Hampshire) was built in 1837-38[96]. The Mississippi and Missouri rivers were operated by team-boats until 1910[97] and the last ferry of this type remained in service until the end of the 1920s on the Cumberland River in Tennessee[98].

5. Conclusions

However, the end of this experimentation was in the air and the first signs were a consequence of the development of steam propulsion. The experiences of Denis Papin (1647 - 1713), of Jonathan Hulls, of the Marquis Jouffroy d'Abbans (1751 - 1832)

[92] Wheeling, Ken. Crossing the Waters - By Horse and Ferry, That Is, *The Carriage Journal*, Vol. 27, No. 4 (Spring 1990), p. 183; Boyer, Charles Shimer. *Annales of Camden*, n. 3 (1921). Old ferries, Camden, New Jersey [Camden, N.J.] Privately printed, 1921; p. 7, 11, 15, 17, 20-21; Stuart, James. *Three Years in North America*. Vol. 1. Edinburgh: R. Cadell 1833; p. 51 and Tenkotte, Paul A. & James C. Claypool. *The Encyclopedia of Northern Kentucky*. Lexington: The University Press of Kentucky, 2009; p. 324-25.

[93] *Robertson's landmarks of Toronto: a collection of historical sketches of the old town of York from 1792 until 1833, and of Toronto from 1834 to 1895…* . Toronto: J. Ross Robertson, 1896; p. 762-763.

[94] Mackey, F. *Steamboat Connections: Montreal to Upper Canada, 1816 - 1843*. Montreal & Kingston: McGill-Queen's University Press, 2000; p. 234.

[95] Fisler, L.F. *A local History of Camden…* . Camden, NJ: Francis A. Cassedy, 1858; p. 17-36.

[96] Parker, Benjamin Franklin. *History of Wolfeborough (New Hampshire)*. Cambridge, Mass.: Published by the Town (Press of Caustic & Claflin), 1901; p. 509.

[97] Shomette, Donald G. Heyday of the Horse Ferry, *National Geographic Magazine*. Vol. 176, N. 4 (Oct. 1989), p. 549–556.

[98] Dillehay, Tilly. Remembering Rome Ferry. *Wilson Living Magazine*, July 30, 2013.

from 1778 to 1783[99], and of Claude François Joseph Count d'Auxiron (1731 - 1778), in 1774, which they developed throughout the eighteenth century and the early years of the following century, were the paradigm shift in river, lake and then maritime navigation. Thanks to the continuous improvements to the steam engine, to the paddle wheel, but above all to the dimensions of the boats that became increasingly larger and more reliable in terms of navigation and transport, the success of the experience of vessels propelled by animal propulsion, in the first quarter of the nineteenth century, was soon overshadowed by the steamboat that took over this navigation system. Advances in the technique of building steamboats made so much progress in so few years that in the nineteenth century steam transmission became *de facto* "modern" technology that will see an enormous amount of patents and inventions proliferate, but above all shipbuilding that they will become the *princeps* type of naval propulsion in the following centuries[100]. Wheel propulsion driven by animal force will then be remembered as a romantic experience within a scientific-technical revolution that will definitely change the way people navigates.

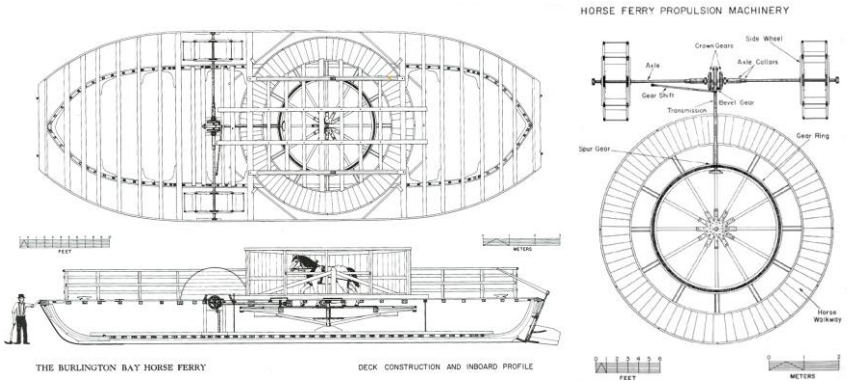

Figure 5. The Burlington Bay Horse ferry, draw by K. Crisman, found in 1983 in Lake Champlain. By Crisman, K. J. and A. B. Cohn. *When Horses Walked on Water. Horse-powered Ferries in Nineteenth-Century America*. Washington & London: Smithsonian Institution Press, 1988; p. 217. The dimensions of the hull of the ferry were: length 18.4 meters, width 4.6 meters; while the dimensions of the bridge were: length 19 meters and width 7.2 meters.

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