THE

STEAM ENGINE

EXPLAINED AND ILLUSTRATED;

WITH

AN ACCOUNT OF ITS INVENTION AND PROGRESSIVE IMPROVEMENT,

AND ITS APPLICATION TO

NAVIGATION AND RAILWAYS;

INCLUDING ALSO

A Memoir of Watt.

BY

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&c. &c.

SEVENTH EDITION,

ILLUSTRATED BY ENGRAVINGS ON WOOD.

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attached so as to be steam-tight to the bottom of the piston. A hollow space L L is cast in the bottom of the cylinder for the reception of the box K K, when the piston is at the bottom of the cylinder.

By this arrangement the force by which the piston is driven in its ascent and descent is communicated to the connecting rod, not, as usual, through the intervention of a piston-rod, but directly from the piston itself by the cross-pin I, and from thence to the crank C, which it drives without the intervention of beams, cross-heads, or any similar appendage.

The slide-valves regulating the admission and eduction of steam are represented at *a*; the rod of the air-pump is shown at *d*, being worked by a crank placed on the centre of the great crank shaft.*

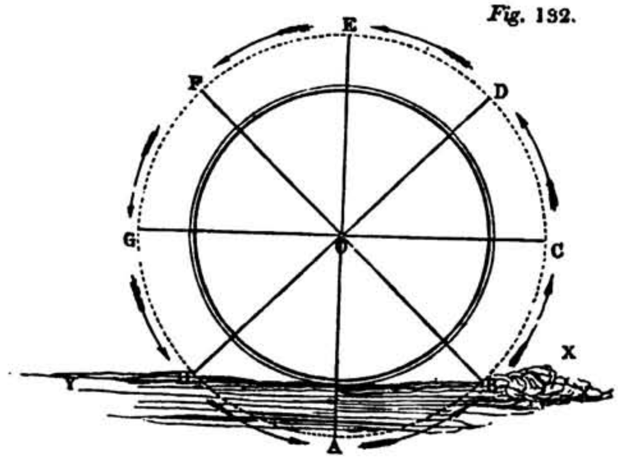
(222.) To obtain from the moving power its full amount of mechanical effect in propelling the vessel, it would be necessary that its force should propel, by constantly acting against the water in a horizontal direction, and with a motion contrary to the course of the vessel. No system of mechanical propellers has, however, yet been contrived capable of perfectly accomplishing this. Patents have been granted for many ingenious mechanical combinations to impart to the propelling surfaces such angles as appeared to the respective contrivers most advantageous. In most of these the mechanical complexity has formed a fatal objection. No part of the machinery of a steam-vessel is so liable to become deranged at sea as the paddle-wheels; and, therefore, that simplicity of construction which is compatible with those repairs which are possible on such emergencies is quite essential for safe practical use.

The ordinary paddle-wheel, as has been already stated, is a wheel revolving upon a shaft driven by the engine, and carrying upon its circumference a number of flat boards, called paddle-boards, which are secured by nuts and braces in a fixed position; and that position is such that the planes

* Engines on a very large scale constructed upon this principle are said to be in process of construction for an iron steam-vessel of great tonnage, which is in preparation for the New York passage. It is said that the cylinders of these engines will be one hundred and twenty inches in diameter.

of the paddle-boards diverge nearly from the centre of the shaft on which the wheel turns. The consequence of this arrangement is that each paddle-board can only act in that direction which is most advantageous for the propulsion of the vessel when it arrives near the lowest point of the wheel. In *fig.* 132. let O be the shaft on which the common paddle-

Fig. 132.



wheel revolves; the position of the paddle-boards are represented at A, B, C, &c.; X, Y represents the water line, the course of the vessel being supposed to be from X to Y; the arrows represent the direction in which the paddle-wheel revolves. The wheel is immersed to the depth of the lowest paddle-board, since a less degree of immersion would render a portion of the surface of each paddle-board mechanically useless. In the position A the whole force of the paddle-board is efficient for propelling the vessel; but as the paddle enters the water in the position H, its action upon the water, not being horizontal, is only partially effective for propulsion: a part of the force which drives the paddle is expended in depressing the water, and the remainder in driving it contrary to the course of the vessel, and, therefore, by its re-action producing a certain propelling effect. The tendency, however, of the paddle entering the water at H, is to form a hollow or trough, which the water, by its ordinary property, has a continual tendency to fill up. After passing the lowest point A, as the paddle approaches the position B, where it emerges from the water, its action again becomes oblique, a part only having a propelling effect, and the remainder having a tendency to raise the water, and throw up a wave and spray behind the paddle-wheel. It is evident that the more deeply the paddle-wheel becomes immersed, the greater will be the proportion of the propelling power thus wasted in elevating and depressing the water; and if the wheel were immersed to its axis, the whole force of the paddle-boards, on entering and leaving the water, would be lost, no part of it having a tendency to propel. If a still deeper immersion take place, the paddle-boards above the axis would have a tendency to retard the course of the vessel. When the vessel is, therefore, in proper trim, the immersion should not exceed nor fall short of the depth of the lowest paddle; but for various reasons it is impossible in practice to maintain this fixed immersion: the agitation of the surface of the sea, causing the vessel to roll, will necessarily produce a great variation in the immersion of the paddle-wheels, one becoming frequently immersed to its axle, while the other is raised altogether out of the water. Also the draught of water of the vessel is liable to change, by the variation in her cargo; this will necessarily happen in steamers which take long voyages. At starting they are heavily laden with fuel, which as they proceed is gradually consumed, whereby the vessel is lightened.

(223.) To remove this defect, and economise as much as possible the propelling effect of the paddle-boards, it would be necessary so to construct them that they may enter and leave the water edgeways, or as nearly so as possible; such an arrangement would be, in effect, equivalent to the process called feathering, as applied to oars. Any mechanism which would perfectly accomplish this would cause the paddles to work in almost perfect silence, and would very nearly remove the inconvenient and injurious vibration which is produced by the action of the common paddles. But the construction of feathering paddles is attended with great difficulty, under the peculiar circumstances in which such wheels work. Any mechanism so complex that it could not be easily repaired when deranged, with such engineering implements and skill as can be obtained at sea, would be attended with great objections; and the efficiency of its propelling action would not compensate for the dangers which must attend upon the helpless state of a steamer, deprived of her propelling agents.

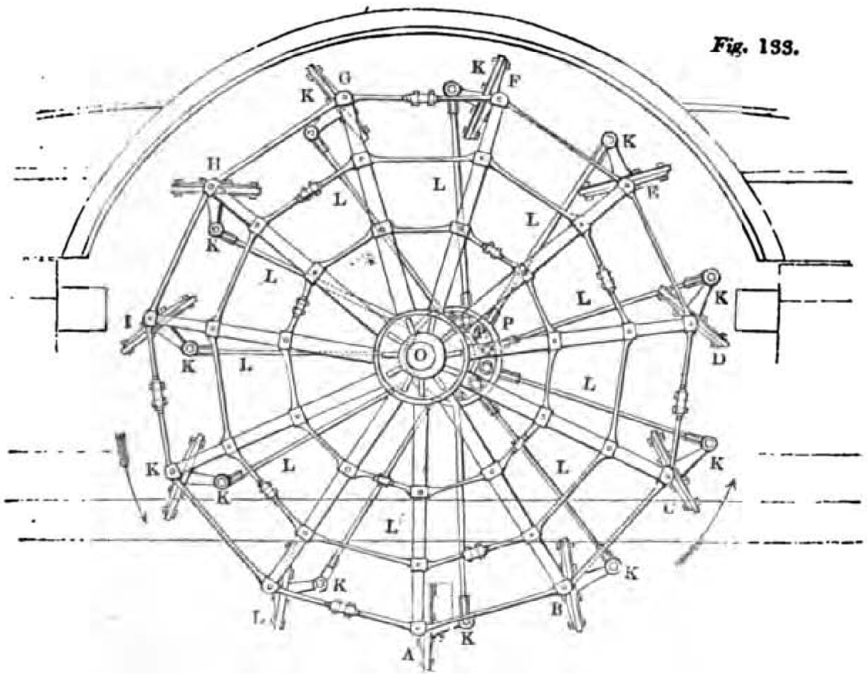
Feathering paddle-boards must necessarily have a motion independently of the motion of the wheel, since any fixed position which could be given to them, though it might be most favourable to their action in one position would not be so in their whole course through the water. Thus the paddle-board when at the lowest point should be in a vertical position, or so placed that its plane, if continued upwards, would pass through the axis of the wheel. In other positions, however, as it passes through the water, it should present its upper edge, not towards the axle of the wheel, but towards a point above the highest point of the wheel. The precise point to which the edge of the paddle-board should be directed is capable of mathematical determination. But it will vary according to circumstances, which depend on the motion of the vessel. The progressive motion of the vessel, independently of the wind or current, must obviously be slower than the motion of the paddle-boards round the axle of the wheel; since it is by the difference of these velocities that the re-action of the water is produced by which the vessel is propelled. The proportion, however, between the progressive speed of the vessel and the rotative speed of the paddle-boards is not fixed: it will vary with the shape and structure of the vessel, and with its depth of immersion; nevertheless it is upon this proportion that the manner in which the paddle-boards should shift their position must be determined. If the progressive speed of the vessel were nearly equal to the rotative speed of the paddle-boards, the latter should so shift their position that their upper edges should be presented to a point very little above the highest point of the wheel. This is a state of things which could only take place in the case of a steamer of a small draught of water, shallop-shaped, and so constructed as to suffer little resistance from the fluid. On the other hand, the greater the depth of immersion, and the less fine the lines of the vessel, the greater will be the resistance in passing through the water, and the greater will be the proportion which the rotative speed of the paddle-boards will bear to the progressive speed of the vessel. In this latter case the independent motion of the paddle-boards should be such that their edges, while in the water, shall be presented towards a point considerably above the highest point of the paddle-wheel.

A vast number of ingenious mechanical contrivances have been invented and patented for accomplishing the object just explained. Some of these have failed from the circumstance of their inventors not clearly understanding what precise motion it was necessary to impart to the paddle-board: others have failed from the complexity of the mechanism by which the desired effect was produced.

(224.) In the year 1829 a patent was granted to Elijah Galloway for a paddle-wheel with movable paddles, which patent was purchased by Mr. William Morgan, who made various alterations in the mechanism, not very materially departing from the principle of the invention.

This paddle-wheel is represented in *fig.* 133. The contrivance may be shortly stated to consist in causing the wheel which bears the paddles to revolve on one centre, and the radial arms which move the paddles to revolve on another centre. Let A B C D E F G H I K L be the polygonal circumference of the paddle-wheel, formed of straight bars, securely connected together at the extremities of the spokes or radii of the wheel which turns on the shaft which is worked by the engine; the centre of this wheel being at O. So far this wheel is similar to the common paddle-wheel; but the paddle-boards are not, as in the common wheel, fixed at A B C, &c., so as to be always directed to the centre O, but are so placed that they are capable of turning on axles which are always horizontal, so that they can take any angle with respect to the water which may be given to them. From the centres, or the line joining the pivots on which these paddle-boards turn, there proceed short arms K, firmly fixed to the paddle-boards at an angle of about 120°. On a motion given to this arm K, it will therefore give a corresponding angular motion to the paddle-board, so as to make it turn on its pivots. At the extremities of the several arms marked K is a pin or pivot, to which the extremities of the radial arms L are severally

Fig. 133.



attached, so that the angle between each radial arm L and the short paddle-arm K is capable of being changed by any motion imparted to L; the radial arms are connected at the other end with a centre, round which they are capable of revolving. Now, since the points A B C, &c., which are the pivots on which the paddle-boards turn, are moved in the circumference of a circle, of which the centre is O, they are always at the same distance from that point; consequently they will continually vary their distance from the other centre P. Thus, when a paddle-board arrives at that point of its revolution at which the centre round which it revolves lies precisely between it and the centre O, its distance from the former centre is less than in any other position. As it departs from that point, its distance from that centre gradually increases until it arrives at the opposite point of its revolution, where the centre O is exactly between it and the former centre; then the distance of the paddle-board from the former centre is greatest.

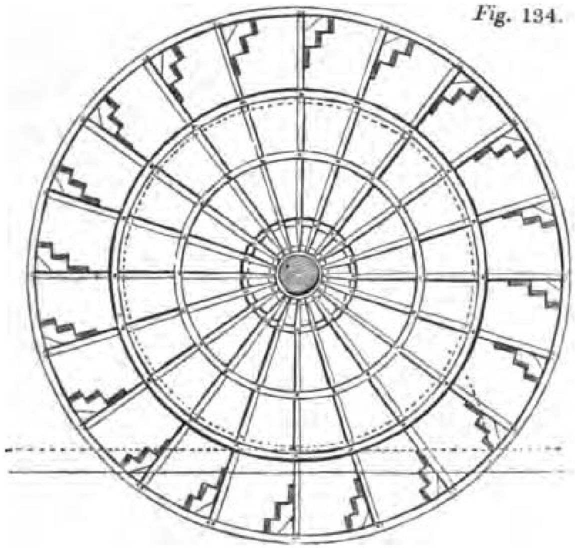
This constant change of distance between each paddle-board and the centre P is accommodated by the variation of the angle between the radial arm L and the short paddle-board arm K; as the paddle-board approaches the centre P this gradually diminishes; and as the distance of the paddle-board increases, the angle is likewise augmented. This change in the magnitude of the angle, which thus accommodates the varying position of the paddle-board with respect to the centre P, will be observed in the figure. The paddle-board D is nearest to P; and it will be observed that the angle contained between L and K is there very acute; at E the angle between L and K increases, but is still acute; at G it increases to a right angle; at H it becomes obtuse; and at K, where it is most distant from the centre P, it becomes most obtuse. It again diminishes at K, and becomes a right angle between A and B. Now this continual shifting of the direction of the short arm K is necessarily accompanied by an equivalent change of position in the paddle-board to which it is attached; and the position of the second centre P is, or may be, so adjusted that this paddle-board, as it enters the water and emerges from it, shall be such as shall be most advantageous for propelling the vessel, and therefore attended with less of that vibration which arises chiefly from the alternate depression and elevation of the water, owing to the oblique action of the paddle-boards.

(225.) In the year 1833, Mr. Field, of the firm of Maudslay and Field, constructed a paddle-wheel with fixed paddle-boards, but each board being divided into several narrow slips arranged one a little behind the other, as represented in *fig.* 134. These divided boards he proposed to arrange in such cycloidal curves that they must all enter the water at the same place in immediate succession, avoiding the shock produced by the entrance of the common board. These split paddle-boards are as efficient in propelling when at the lowest point as the common paddle-boards, and when they emerge the water escapes simultaneously from each narrow board, and is not thrown up, as is the case with common paddle-boards.*

* A patent was subsequently taken out for these by Mr. Galloway. Mr.

The theoretical effect of this wheel is the same as that of the common wheel, and experience alone, the result of

Fig. 134.



which has not yet been obtained, can prove its efficiency. The number of bars, or separate parts into which each paddle-board is divided, has been very various. When first introduced by Mr. Galloway each board was divided into six or seven parts: this was subsequently reduced, and in the more recent wheels of this form constructed for the government vessels the paddle-boards consist only of two parts, coming as near to the common wheel as is possible, without altogether abandoning the principle of the split paddle.

(226.) To obtain an approximate estimate of the extent to which steam-power is applicable to long sea-voyages, it would be necessary to investigate the mutual relation which, in the existing state of this application of steam-power, exists between the capacity or tonnage of the vessel, the magnitude, weight, and power, of the machinery, the available stowage for fuel, and the average speed attainable in all

Field did not persevere in its use at the time he invented it. It has, however, been more generally adopted since the date of Galloway's patent.

THE

PENNY CYCLOPÆDIA

OF

THE SOCIETY

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DIFFUSION OF USEFUL KNOWLEDGE.

VOLUME XXII.

SIGONIO——STEAM-VESSEL.

LONDON:
CHARLES KNIGHT AND Co., 22, LUDGATE STREET.

MDCCCXLII.

Price Seven Shillings and Sixpence, bound in cloth.

working the boiler with fresh water only, or by using sea-water with such precautions as may prevent the injurious deposition of salt. Of the latter class of measures that called *blowing-out* may be first alluded to. It consists in allowing a large quantity of water to escape from the boiler into the sea, whenever it is becoming so salt as to render the deposition of sediment likely to commence, and supplying its place with the comparatively fresh water from the condenser. As that portion of the water which contains the greatest proportion of salt sinks, by its greater specific gravity, to the bottom of the boiler, the blow-off cocks are usually placed very low down. It is usual to blow out a portion of the water about every two hours; but, as the performance of the operation involves loss of fuel, from the coldness of the water introduced to restore the proper level, it is very desirable to avoid blowing out too often, as well as to avoid delaying it too long. A beautiful contrivance for indicating when the operation is necessary has been recently introduced by Messrs. Seaward, consisting of a glass gauge communicating with the boiler, and containing two hydrometer balls, of slightly different weight, so adjusted that neither of them will float in common sea-water, which contains about $\frac{1}{33}$ part of its weight of salt, but that the lighter one will float when the proportion of salt rises to $\frac{4}{33}$, and the heavier one when it is more than $\frac{5}{33}$ parts. Deposition takes places when the salt amounts to $\frac{8}{33}$ parts. Thus the rising of one or other of the balls indicates the degree of saltness, and the proper time for blowing-out. Messrs. Seaward also use an apparatus by which the water is blown into a separate chamber before it is turned into the sea, and this chamber, being made to contain exactly a ton of water, prevents the accidental discharge of too large a body of water at once, while the valves are so arranged that no negligence can possibly occasion the boiler to be left in communication with the sea. Messrs. Maudslay and Field adopt a different method for preserving the proper state of the water, using pumps, called *brine-pumps*, to remove constantly a small portion of water from the lower part of the boiler. When these are used, the feed-pumps are made to inject an extra quantity of water, to take the place of that removed by the brine-pumps, and the current of hot brine is conducted along a pipe which passes through the feed-pipe, by which means much of its heat is imparted to the water entering the boiler. This apparatus appears to be very effectual, and has been tried in the Great Western and other steam-vessels. The use of copper instead of iron as a material for boilers lessens the evil attending the use of salt-water, as the sedimentary matter does not form a crust upon it, but is precipitated in a loose form, and easily removed by blowing-out; but both materials are alike subject to another serious evil—the rapid corrosion of the flues by the chemical action of the soot, when mixed with salt, of which minute particles will escape through the joints in spite of every precaution. This evil can only be avoided by the use of fresh-water in the boilers, a measure which, in sea-voyages, cannot be adopted without the use of a condensing-apparatus of such construction as to preserve the condensed steam free from any admixture of sea-water. This is accomplished by what is termed surface or dry condensation; a method which has been repeatedly tried, from the days of Watt to the present time, but which has never, we believe it may be safely affirmed, been found equally efficient with the condensation by jet. In the case of steam navigation, however, although no advantage may be gained in the act of condensation, the method may be highly advantageous, because, by saving all the water produced by condensation, and returning it to the boiler, the use of sea-water may be avoided. Mr. Samuel Hall, who is also the author of several other inventions connected with steam navigation, has laboured with more success than most experimentalists in this important attempt to obviate what has been shown to be a very serious difficulty. His condenser consists of a great number of small tubes, kept at a low temperature by means of cold water, of which a copious supply is made to flow around them. The steam passes through these tubes, and is condensed by their coldness; and to prevent, as far as possible, any waste of the fresh water with which the boiler is to be fed, the steam which escapes from the safety-valves, as well as that from the cylinders, is conducted to the condenser. Another invention in which the steam is constantly reproduced from the same water, is that commonly known as Howard's Vapour-Engine. Here a boiler, in the ordinary sense of the term, is dispensed with; steam being formed by injecting a small quantity of water on to the surface of mercury, which is heated in a shallow iron vessel, over a coke fire, to a temperature of 300° or 400°. The mercury is covered with a thin plate of iron; so that, although it is the medium by which heat is communicated, the water is never in actual contact with it. Further information respecting this and several of the other inventions alluded to in this part of our subject, may be found in the seventh edition of Lardner on the Steam-Engine.

In the construction and arrangement of marine boilers, safety, and the power of generating steam with great rapidity, are the grand requisites. The furnaces should be, as much as possible, surrounded with water; and, to economise heat, as well as to avoid the injurious effect of its radiation upon the vessel, the boilers and steam-pipes should be coated with felt, which is applied to the surface by means of a thick covering of white and red lead. 'This expedient,' says Lardner, 'was first applied in the year 1818 to a private steam-vessel of Mr. Watt's, called the Caledonia.' The boilers, of which there are three or four in most large vessels, are placed side by side across the vessel, immediately in the rear of the engines, and their flues are usually conducted into one large funnel or chimney. The boilers of sea-going vessels should be so arranged that any one of them may be emptied, and repaired or cleaned, during a voyage, without impeding the use of the others or stopping the engines.

The frame-work of the engines should be so contrived as to relieve the vessel as far as possible from strain, by causing the inevitable strain of the machinery to be, as it is termed, self-contained. The general arrangement should also be such as to allow free access to every part, and to bring the valve-gear within convenient reach of the engineer. In all the engines hitherto described, excepting those of Bell's Comet, the power of the engines is communicated at once to the paddle-shaft; but this, while by far the most common, is not the universal arrangement. In some towing-vessels, for instance, where great power is requisite, but speed is of minor importance, the paddle-wheels are mounted on a separate axis, which, by means of toothed gear, receives a slower motion than the crank-shaft turned by the engines.

It remains to notice, in connection with marine steam-engines, the question as to the best proportion of steam-power to the tonnage of a vessel, a question upon which very different opinions are entertained. In most of the early steam-vessels, a very low proportion of power was used; but experience has, in most cases, shown the superior economy attending the use of powerful machinery, capable of propelling the vessel at a high speed. It is not pretended that, simply considered, a high velocity can be maintained as cheaply as a slow one; but, independent of mere speed under favourable circumstances, it is essential that a steam-vessel should be able to make way against adverse winds and currents, without any very great diminution of velocity; and its power of doing this, in which its regularity and ultimate economy greatly consists, increases in proportion to the degree in which its average speed in still water exceeds the speed of the winds or currents which may be opposed to its progress. Thus a steam-vessel with a mean speed of six miles an hour, if opposed to a current of three miles an hour, will only move at half her usual rate, thereby occasioning great irregularity in the time of her voyages, and a very wasteful consumption of fuel; while a vessel whose mean speed is nine miles an hour will, under like circumstances, merely be reduced to two-thirds of her average speed. Hence, although the consumption of fuel increases in a larger ratio than the increase of speed, it may, in many cases, prove more economical to use a very powerful engine, capable of performing the required voyages with tolerable regularity in all weathers, than one of less power, which, though it may attain a moderate speed with less cost in fine weather, will be almost brought to a stand under difficult circumstances. In British steam-vessels the proportion usually ranges between two and four tons measurement to each horse-power.

Notwithstanding the defects commonly imputed to it, and the great number of contrivances which have been devised for avoiding them, the common paddle-wheel continues to be the only means of propulsion commonly used. It consists of a number of flat boards, called float-boards or paddles, bolted to the radii or arms of a light but strong iron wheel, which is fixed securely upon the crank axis of the engine, and it should be so placed that the lowest float-board is entirely immersed in the water. It is evident that the paddles produce the greatest effect in propelling the vessel when they are in or very near a vertical position; and it is urged as an objection to the common paddle-wheel, that the float-boards necessarily enter and leave the water in an inclined position; so that in entering they have a tendency, by pressing upon its surface, to lift the vessel out of the water, while in leaving the water they have the contrary effect, tending to depress the vessel, and to throw back the water, thereby occasioning a heavy swell. This evil is however less than might be supposed from a hasty consideration of the subject, as the motion of the paddles is not simply that of revolving round an axis, but that of revolving round an axis which is continually moving forward; so that, although the evils adverted to may be very apparent in starting the vessel, they disappear in a great measure when it moves with considerable speed. The action of a paddle-wheel of the common and of several modified forms may be more readily comprehended by the diagrams published in the new edition of Tredgold on the Steam-engine, than by any mere description; but it may be sufficient here to quote the words of Russell, who, after tracing the motion of a paddle of the common form during the progress of the vessel, comes to the conclusion that it 'is inserted into the water in an angular position, resembling closely the entrance of an oar into the water; that it is then made to act horizontally on the water during a short interval, after which it is withdrawn from the water edgeways, in an easy and elegant manner, which the dexterous rower might envy and try to equal, but which he could hardly excel.' It is admitted that, in order to the attainment of this perfect action, it is necessary that the paddle and the boat be well proportioned and placed; yet the writer argues that 'the common paddle-wheel is in practice, as it ought to be in theory, exempt from the faults generally attributed to it.' Perhaps, so far as regards mere efficiency as a propeller, this may be correct; but few will deny that some means of propulsion which shall occasion less agitation in the water, and less vibration in the vessel, is a desideratum. Several improvements upon the common paddle-wheel have been introduced, which tend to diminish the defects attributed to it. Among these is the divided paddle-wheel, which was invented by the younger (American) Stevens, and is commonly used in the steam-vessels of North America, which often have very large paddle-wheels. In this kind of wheel the float-boards, instead of extending the whole width of the wheel, are in two or sometimes three sets, each of which extends across only one-half or one-third of the width; one set of float-boards being placed opposite to the intervals of the other set. *Figs.* 8 and 9 give side and front views of such a wheel; the

Fig. 8.

Fig. 9.

shaded parts in *Fig.* 8 being those which belong to the off-side of the wheel. This kind of wheel resembles in fact two or three narrow paddle-wheels placed close together on the same axis, the paddles of one being opposite to the intervals of that adjoining it. By this means the shock occasioned by the paddles entering the water is diminished, and the resistance is rendered more equal. Another kind of divided paddle is that in which the float-boards extend across the whole width of the wheel, but each of them consists of two, three, or more narrow strips, placed a little in advance of each other, so as to strike the water at slightly different times. *Fig.* 10 represents such a wheel, with the paddles divided into three parts. Under the name of the *cycloidal* paddle-wheel this has excited much attention. It has been used with apparent advantage in the Great

Fig. 10.

Western and many other sea-steamers. A similar advantage is attained by the expedient of dividing the float-board into three slips, and bolting one of them on the opposite side of the arm of the wheel to the other two. Many of the contrivances intended as improvements on the common paddle-wheel have moveable float-boards, which, by various ingenious arrangements, are made to enter and leave the water in a nearly vertical position. The unavoidable complexity of such an apparatus, which renders it very liable to derangement, is fully sufficient to prevent its extensive use; yet a wheel of this kind, known as Morgan's paddle-wheel, has been adopted in several large vessels. Professor Barlow in a paper 'On the Motion of Steam-Vessels,' which was published in the 'Philosophical Transactions' in 1834, and subsequently, with additions, in the appendix to Woolhouse's edition of Tredgold, expresses his belief, after trying experiments on different kinds of paddle-wheel, that when the wheel is but slightly immersed, little or no advantage is derived from the vertical position of the paddles, and 'that in the navigation of rivers or smooth water, where generally little variation is required in the degree of immersion of the vessel, the common wheel, if properly proportioned, is preferable to the vertically acting wheel, in consequence of its admitting a larger surface of paddle-board.' On the other hand, as the vertical paddles have greatly the advantage when the wheel is deeply immersed, he considers them best 'for sea purposes or long voyages, where the immersion of the vessel is constantly diminishing by the exhaustion of the coals and stores required at the commencement of the voyage.'

Another class of paddle-wheels have the float-boards placed obliquely across the width of the wheel, instead of in the usual position; and some have one-half of their width inclining one way, and the other half in the opposite direction. The paddle-wheels patented in 1836 by Mr. Samuel Hall were intended to reduce the tremulous motion of the vessel, and the quantity of back-water, by affixing the paddle-boards on one-half of the circumference of the wheel with an obliquity in one direction, and those on the other half with a contrary inclination; so that during one-half of the revolution of each paddle-wheel the water should be put in motion in one direction, and during the other half of the revolution it should be moved in the opposite direction. Mr. Hall states that the angle of obliquity may vary from 30° to 60°, but that he prefers 45°, and he proposes in large wheels to vary the inclination four times instead of twice in the circumference. A very singular scheme for propelling is that patented by Mr. Perkins in 1829, in which the paddles are fixed at an angle of 45° with the wheel, and the wheel itself is placed at an angle of 45° with the line of the keel; so that while the paddles enter and leave the water edgeways, they assume the most effective position for propelling when performing the lowest part of the revolution. Full details of this ingenious contrivance may be found in the 'Mechanics' Magazine,' vol. xiv., p. 305, &c. Conical paddle-wheels, resembling those of the common form, excepting in the circumstance of the diameter being greater on the side adjoining the vessel than on the outer side, have been tried by Mr. Russell, who says that they prevent much of the concussion of the common wheel, without any sacrifice of power or speed. Some proposed paddle-wheel improvements have reference to the convenient adaptation of the paddles to the depth of the vessel's immersion. Something of this kind is very desirable, because it often happens that a vessel is, in consequence of a heavy load and a large stock of fuel, so deeply immersed at the commencement of her voyage that the action of her paddles is impeded; while, after the consumption of great part of her supply of coal, she swims so high that her paddles have not sufficient hold upon the water. When the paddle-wheels are fixed immediately upon the crank axis of the engine, it is impossible, without too great a derangement of the machinery, to make the paddle-shaft itself rise and fall according to circumstances; and although many plans have been proposed for reefing the paddles, or removing them to a greater or less distance from the centre of the wheel, we believe that none has been introduced to any important extent. In some steam-vessels the inconvenience alluded to is in some degree remedied by admitting sea-water into the coal bunkers when they are emptied, so as to maintain a uniform degree of immersion. It would often be a convenience if, instead of being firmly keyed on to the shaft, the paddle-wheels were capable of being detached from the engines, so that either might move independently of the other. Many of the American steamers have such a provision, whereby the boat may be stopped by simply throwing the wheels out of gear, the engines continuing to work, so as to pump water into the boiler. By this means also the paddle-wheels are preserved from strains while the vessel lies at anchor, exposed to the influence of tides.

In noticing some of the early projects connected with steam navigation, allusion has been made to several other methods of propulsion, some of which have been revived of late years. Our space will not allow of any account of the numerous schemes which have been propounded for moving vessels by contrivances which have been expected to prove superior to paddle-wheels, either from producing a greater effect with a given exertion of power, from superior compactness, or from occasioning less disturbance in the water. Some apparatus that would effect the latter object without the sacrifice of power or speed, appears very desirable; and among many inventions which have been tried for the purpose, that commonly, though not very aptly, called the Archimedes' Screw,* appears to succeed very perfectly. It has been tried with considerable success on a large scale. This apparatus has been alluded to under SCREW OF ARCHIMEDES, vol. xxi., p. 111.

The means of diminishing the risk of steam-vessel accidents have been made the subject of parliamentary investigation in 1817, 1831, and 1839; in the latter year by means of commissioners. The valuable information collected on the last occasion has been repeatedly referred to in this article, and our space will not allow an analysis of the important suggestions made for increasing the safety of steam navigation. It is however very satisfactory to find, that while very much remains to be accomplished in this way, the number and character of the accidents which have happened to British steam-vessels will bear a very favourable comparison with those of North America. It is also observable that, while the total number of accidents is by no means large, considering the great number of steam-vessels in use, a considerable proportion of them, and those by far the most fatal in their consequences, were of a character by no means peculiar to vessels propelled by steam. The commissioners give a detailed table of ninety-two accidents which happened between 1817 and April, 1839, of which the following is an abstract. This account is merely given as an approximation to the truth, especially as regards the former years of the period embraced.

Nature of Accidents.	No. of Vessels.	No. of Lives lost.
Wrecked, foundered, or in imminent peril	40	308
†Computed number of persons lost on board the Erin, Frolic, and Superb	..	120
Explosions of boilers . . .	23	77
Fires from various causes . .	17	2
Collisions	12	66
Totals . . .	92	573

In copying this table, we have omitted an item of forty lives lost in the Thames, from May, 1835, to November, 1838, by accidents to barges and small boats by the use of steam-vessels, and a similar item of twenty-one lives lost within ten years in the Clyde, apparently from similar accidents; as these scarcely fall under the denomination of steam-vessel accidents, although they intimate the necessity of increased precaution in the use of steam-vessels upon crowded rivers. It is stated that the greatest number of lives lost at any one time by each of the above classes of accident was as follows:—

Nature of Accident.	Name of Vessel.	Date.	Lives lost.
Wreck . .	Rothsay Castle .	1831	119
Collision . .	Comet and Ayr .	1825	62
Explosion .	Union . . .	1837	24
Fire . . .	Medway . . .	1837	2

The far greater number and more fatal character of steam-vessel accidents in the United States may be seen from the document from which the statistics of American steam navigation given in a previous page were derived. The first accident therein noticed took place in 1816, and the total ascertained number, down to 1838, was as follows:—

Wrecks, from collisions, gales, &c. . .	25
Destroyed by snags and similar obstructions	52
Explosions, &c.	99
Fires	28
Various causes	24
Total	228
Ascertained number of lives lost . .	1,676
Ascertained number of persons wounded	443

The report states that the computed number of lives lost was about two thousand; but that some persons think the aggregate treble that number. The following table gives, in the same form as has been done with British accidents, the most fatal instances of each class of casualties:—

Nature of Accident.	Name of Vessel.	Date.	Lives lost.
Wreck . . .	Home . . .	1837	100
Snags, &c. . .	St. Louis . .	1834	13
Collision (and consequent sinking)	Monmouth .	1837	300
Explosion . . .	Oronoka . .	1838	130
Fire	Ben Sherrod .	1837	130

* It has been stated, but we know not on what authority, that this name has not been intended to imply an identity in principle between the propeller alluded to and the hydraulic machine known as the screw of Archimedes; but has been given simply because it was first tried, on a large scale, in a vessel called the Archimedes. That the vessel was named after the propeller is more likely; but be this as it may, the action of the screw-propeller is very different from that of the screw of Archimedes.

† This item is differently placed in the commissioners' table; but as the difference between the cases to which it refers and those included in the preceding item consists simply in the circumstance that the numbers lost are computed instead of being exactly ascertained, there appears to be no sufficient reason for separating the two. The vessels alluded to were wrecked or foundered and are included in the ninety-two cases classified in the table.

END OF VOLUME THE TWENTY-SECOND.

London: Printed by William Tyler, Bolt-court.

THE

CIVIL ENGINEER AND ARCHITECT'S

JOURNAL,

SCIENTIFIC AND RAILWAY GAZETTE.

VOLUME XII.

1849.

LONDON:

R. GROOMBRIDGE AND SONS, 5, PATERNOSTER ROW; J. WEALE, 59, HIGH HOLBORN; WILEY AND PUTNAM, NEW YORK; GALIGNANI, AND MATHIAS, PARIS.

Printed and Published by WILLIAM LAXTON, the Proprietor, at No. 10, Fludyer Street, Whitehall.

made a revolution, they shall be caused to approach each other, so as to maintain a constant and proper relation to each other for the production of a continuous light.

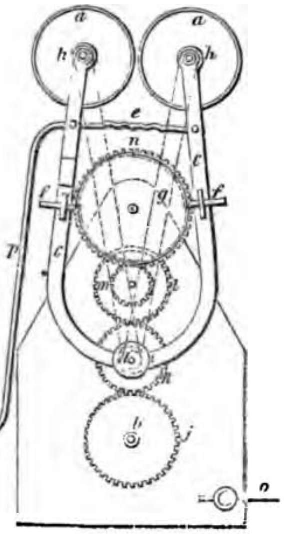


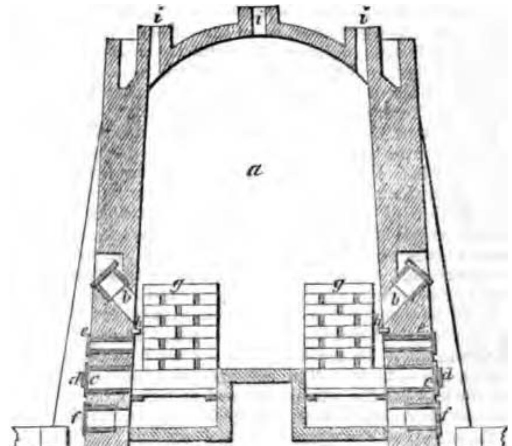
Fig. 5.

Fig. 5 is an elevation of the apparatus employed in carrying out this part of the invention. *a*, *a*, are two electrodes of gas-retort carbon, which are first cut into the form of discs, and then purified by immersion in a solution of nitric and muriatic acid for twelve hours, and afterwards in a solution of fluoric acid for twelve hours. A slow uniform motion may be communicated to the discs by any suitable mechanism; but the patentee prefers to employ that shown in fig. 5, wherein the motion is derived from suitable clock-work, the axis *b*, of which only is shown. The two discs turn on pivots or axes at the upper ends of the arms *c*, *c*; these arms are mounted, at their lower ends, upon an axis *d*, so as to move freely thereon; and the upper ends of the arms are continually drawn towards each other by a spring *e*, but are prevented from approaching too closely by the pieces *f*, *f*, which bear against the periphery of the eccentric or step-wheel *g*. The two discs are caused to rotate by means of two endless chains or bands, passing around the pulleys *h*, *h*, on the axes of the discs, and around a pulley *i*, fixed to a toothed-wheel *k*, which gears into another toothed-wheel *j*, on the axis *b*. Rotary motion is also given to the eccentric or step-wheel *g*, by means of the train of wheels *j*, *k*, *l*, *m*, *n*; so that, when the discs have made a complete revolution, the wheel *g*, may present a deeper step or depression to each of the pieces *f*, *f*, and thus permit the arms *c*, *c*, to approach nearer to each other, in order to compensate for the wear of the two electrodes. *o*, *p*, are the wires connected with the battery. The part marked with a * is made of some non-conducting material; and the other parts are made of metal. It is not essential that the two electrodes should rotate in the same plane, as they may rotate in planes at right angles to each other. The patentee states that he does not confine himself to the use of two discs, as a single disc may be employed with another form of electrode.

The patentee claims—Firstly, the application of that description or quality of carbon obtained by the destructive distillation of coal and other matters, such as are used in the manufacture of gas, as one of the elements of an electric pile; also the employment of carbon moulded and subjected to pressure and manufactured as above described; also the electrotyping the ends of carbon used as elements in electric-piles; also the connecting of carbon elements of an electric pile with other elements used, by soldering, or by other permanent fixture. Secondly, the so applying two discs of carbon as electrodes that they shall (when they have completed a revolution) be caused by the mechanism to approach to each other, and thus obtain a continuous light by electricity.

BRICK AND TILE KILN.

William Swaine, of Pembridge, Hereford, brick-maker, for "*improvements in kilns for burning bricks, tiles, and other earthen substances.*"—Granted July 18, 1848; Enrolled January 18, 1849.



The improvement relates to the construction of a kiln, as shown in the annexed engraving, which is a transverse section. *a*, is the kiln; *b*, the feeding-places, kept closed excepting when fuel is introduced; *c*, furnace-doors, formed with an opening for the introduction of a rake, to rake the fire without opening the doors, the opening is closed at other times by a small door *d*; *e*, air-pipes; *f*, ash-pit doors; *g*, fire-boxes, built of fire-bricks, with holes between the bricks, similar to those heretofore used in some kilns; *h*, brick ledges, for throwing off the coals as they pass through the feeding-pipes; and *i*, chimneys, of which there are nine. The doors must be made to fit closely, in order that the passage of air into the fire-places and kiln may be partially or entirely stopped, so that the fires may be regulated with great nicety, and, when necessary, may prevent combustion, by stopping the supply of air.

SHIPS AND PADDLE-WHEELS.

James Taylor, of Furnival's-inn, gentleman, for "*improvements in propelling ships and other vessels.*"—Granted December 2, 1848; Enrolled January 27, 1849. [Reported in the *Patent Journal.*]

The specification describes, in addition to a mode of propelling vessels, a form of construction of vessels generally; the first part of the specification describing the mode of forming the mould or model of the vessel; the second, the construction of a paddle or propelling wheel; and the third, the constructing the parts of the vessel for the reception of this paddle-wheel. The patentee gives rather a vague rule for the moulds or models of ships and vessels. He proposes to form the 'midship section of the vessel of an ellipse, the longest diameter being the horizontal one, and the shortest the vertical. As the cross sections approach the stem and stern posts, the horizontal diameters become gradually less, while the vertical diameter remains the same until a certain point between the 'midship section and the stem or stern, where the horizontal diameter becomes equal to the vertical; or, in other words, the cross section of the vessel is a circle; from this point to the stem or stern posts, the order of the ellipses forming the cross sections are reversed—that is, the vertical diameter remains precisely the same as before, but is now the longest, and the horizontal diameter the shorter, and gradually becoming less as it approaches the stem and stern posts, to whose shape it at last resolves itself; thus, the patentee states that either obtuse or acute forms of vessels may be constructed, the degrees of acuteness depending upon the proportion the longest diameter of the ellipse at the 'midship section bears to the extreme length of the vessel; the vessel thus constructed, is provided with a keel, the sides of which are concave, so as to agree in contour with the convex form of the hull of the vessel, and is to give the necessary strength as well as to prevent lee-way. The patentee proposes, in the case of sea-going ships and vessels exposed to tempestuous weather, to continue the elliptic form of the vessel above the water-line, and entirely over the deck; but for vessels intended only for the navigation of rivers and smooth waters, then the upper parts of the vessel may be of any shape, but strictly following the rules laid down by him with respect to the hull below the water-line.

The second part consists of a paddle-wheel; this wheel is formed of a large sheet-iron cylinder, upon the sides of which are secured two extending flanges of larger diameter than the cylinder. Between these flanges and the periphery of the cylinder are secured the flats, which are of a curved shape; the depth of the curve being equal to the draught of water of the boat.

The last part of the specification merely describes the means which the patentee proposes to adopt for applying the paddle-wheels to vessels. He proposes in river-going boats to place a single wheel in the middle, an aperture or case being there made for the reception of the same; and from it a trough or way to the stern of the vessel is formed. In sea-going vessels, he proposes to apply two wheels, one placed on each side of the keel, also in a case or aperture. He also proposes to cover this case or aperture with a cap or covering, which is to be secured air and water tight; but it is to be provided with a valve, so situated that when the wash of the sea shall rise in the wheel-case, and expel part of the air therefrom, upon its receding the air shall enter through the valves from the outside. The patentee gives several rules or proportions for making the wheel-case and trough.

He claims generally: First, the mode of forming ships and vessels of the elliptical cross-sections, as described.

Secondly, the construction of the paddle-wheel, as described.

Thirdly, the manner of arranging and applying the paddle-wheel to ships and vessels, as before described.

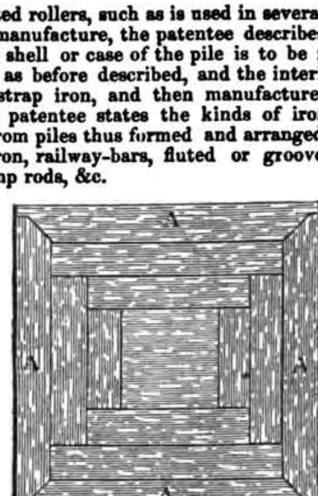
MANUFACTURE OF IRON.

Samuel Lees, of the firm of Hannah Lees and Sons, of Park-road, Lancaster, iron manufacturers, for "*certain improvements in the manufacture of malleable iron.*"—Granted August 8, 1848; Enrolled February 8, 1849. [Reported in the *Patent Journal.*]

The improvements described in this specification relate to the manufacture of malleable iron—first, as to the mode of arranging and forming the piles and faggots, and second, the construction of the machinery to be employed in rolling and manufacturing such piles or faggots into bars, rods, &c.

The first of the improvements consists in placing the plates or bars of iron of which the pile is to be formed, in such manner that the grain of the iron of the several pieces shall be in different relative positions to each other. In the ordinary mode of forming the piles, the flat bars of iron which compose them are merely placed in regular order one upon the other until the required thickness is obtained; the width of the bars being equal to the width of the pile. This mode of piling, when rolled out into bars, rails, &c., presents an exterior surface, upon which the junctions of the bars appear, and thus render them very liable to laminate; as also the strength of the article manufactured is irregular in consequence of the lamilar direction of the grain. This is particularly the case in railway bars, where, by the action of the heavy weights rolling over them, the upper surface is laminated; as also the middle vertical web of the rail is comparatively weak from the cross direction of the grain of the iron. The patentee piles his faggots in the following manner—a cross section of one being shown in the annexed cut. The sides of the pile are formed of plates, or flat bars, A, A, dovetailed at the edges, in the manner shown; or if found more convenient, they may have their edges merely overlapping each other. These plates, when placed together, form the exterior of the shell of the pile, and it will be seen that they present exteriorly their sides; thus the grain of the iron is in a better position. The middle portion is to be filled up by other plates or flat bars, either in the manner shown, or by dovetailing the edges, but in both cases so arranging them that their sides, and consequently the grain of the metal, are in different positions.

The patentee also forms piles in which the exterior shell or case is formed in the manner described, but the interior is filled with plates or flat bars piled or placed in the ordinary manner. He likewise describes and illustrates in the drawings accompanying the specification, a mode of forming the pile from which hollow shafts are to be made. This is formed in nearly the same manner as the preceding, differing only in the employment of two peculiar shaped bars, for the centre of the pile, which when placed together form the hollow or cavity required. For the manufacture of grooved or fluted rollers, such as is used in several of the processes in the cotton manufacture, the patentee describes a mode of proceeding. The shell or case of the pile is to be made of the four plates or bars, as before described, and the interior to be filled up with the best strap iron, and then manufactured up in the usual manner. The patentee states the kinds of iron he proposes to manufacture from piles thus formed and arranged,—as angle-iron, tee-iron, bar-iron, railway-bars, fluted or grooved rollers, shafts piston and pump rods, &c.



The second of the improvements described is that relating to the machinery to be employed for the manufacturing and rolling the piles, formed as above described. This part of the specification is subdivided in two parts. First, the construction of the rollers to be used in rolling the plates or flat bars into the shape desired to form the piles; as also the application to the rollers of a bar or mould, for the purpose of preserving the form of the groove or recess previously formed while passing between the rollers upon its edge. This bar or mould is fixed to the framing of the rollers, and thus allows the grooved bar to slide over it whilst being drawn between the rollers; the bars being successively passed between them until of the proper size.

Thirdly, another of the improvements named in the specification is the employment of two distinct sets of rollers, for rolling the bars, &c., placed side by side, and which are to be driven in opposite directions; so that the bars, after passing through between one set of them, is returned through between the rollers of the other set to its original place before the first set of rollers are ready to be again passed between them,—thus obviating the necessity of returning the bar over the upper roller to its former place in front of them, as is usually the case, thus saving time and facilitating the operation.

The fourth improvement is the mode of supporting the bars of iron as they are passed between the rollers by a carriage over head, and to which a traversing movement is given, for the purpose of bringing the bar of iron before the grooves in the rollers in their proper order; there is also communicated to the carriage a traversing motion for the purpose of bringing it back.

The fifth part describes a mode of straightening bars of iron after having been rolled. This the patentee proposes to do simply by means of their contraction during cooling. The bar to be straightened is taken. while still hot, and placed upon a flat iron plate or bed, to which, by clamps or other convenient means, the ends of the bar are firmly secured; the contraction upon cooling being sufficient to straighten the bar.

The patentee claims: First, the mode of forming the outside of a pile, or faggot of iron, by placing plates or flat bars of iron together at right angles to each other, the edges or corners of them being dovetailed or overlapped, the interior being filled either with scrap iron or with iron plates, whether arranged one upon another or at right angles to each other.

Second, the use and employment of the bar, or mould, attached to rolling mills, for preserving the form and shape of the groove or indentation upon the bar under operation, whilst it is being passed between the rollers upon its edges.

Third, the method described of driving the rollers in opposite directions.

Fourth, the mode described of actuating, and also reversing the movements of the carriage for holding the bars.

Lastly, the mode described of straightening bars of iron, by confining and holding them at their extremities while in a heated state, and by their contraction in cooling assuming a straight line.

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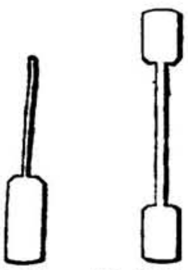
1868
WITH SUBSEQUENT CORRECTIONS

province, from which it is separated by a chain of lofty mountains, some of which, as the Singalang, Merapie, and Sago, attain to nearly 10,000 feet in height; Merapie being an active volcano, the last eruptions of which were in 1845 and 1855, though it sent forth volumes of smoke in 1861. This residency possesses the most lovely districts of the island, or of any tropic land, the mountain slopes being studded with villages, rice-fields, cocoa-nut and coffee trees, of which last, it is calculated that there are 32,000,000 in Upper Padang. In addition to the coffee-culture, gambier, cassia, pepper, ratans, indigo, caoutchouc, &c., are largely produced, and gold, iron, copper, lead, and quicksilver are found. In the district of Tanah Datar is the town of Paggeroejong, formerly the capital of the powerful kingdom of Menangkabo, and the residence of the king.

Tapanoeli, the remaining residency under the government of Sumatra's west coast, lies north-west from Upper Padang. The independent spirit of the inland natives has caused the Netherlanders much trouble, but each fresh outbreak only extends their territory and power further into the interior, and towards the north-west of the island.

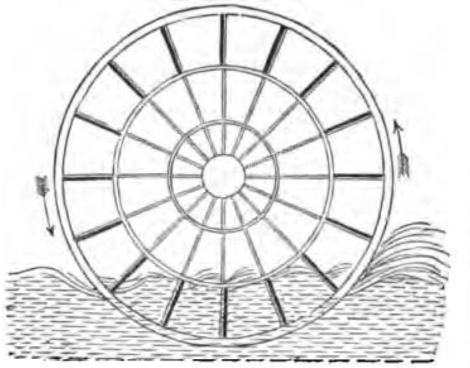
PADDLE, probably the precursor of the OAR (q. v.), and still its substitute among barbarous nations, is a wooden implement, consisting of a wide flat blade with a short handle, by means of which the operator spoons the water towards him. In canoes for only one sitter, a double paddle is generally used, which is dipped alternately on either side: the inhabitants of Greenland are especially skilful in this operation. The action of the paddle is the same as that of the oar. The paddle has, however, one advantage—viz., that the rower faces the bow of his boat, and therefore sees what is before him. In threading narrow streams, &c., this is an appreciable gain.



Paddle. Double Paddle.

PADDLE-WHEEL—one of the appliances in steam-vessels by which the power of the engine is made to act upon the water and produce locomotion—is a skeleton wheel of iron, on the outer portion of whose radii flat boards, called floats or paddles, are fixed, which beat upon the water, and produce, continuously, the same effect as is given, in an intermittent manner, by the blades of oars. The use of paddle-wheels in conjunction with steam as a motive-power dates from about the commencement of the present century, but the employment of the paddle-wheel itself is as ancient as the time of the Egyptians. A specimen is also known to have been tried in Spain in the 16th century.

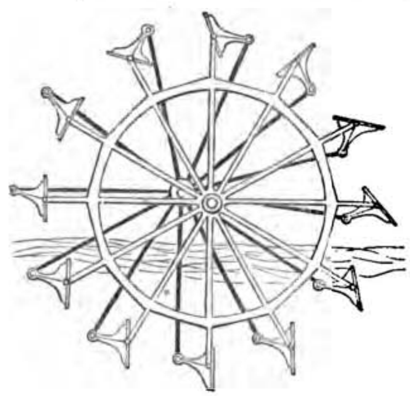
The fig. shews the usual form of paddle-wheel, that called the radial, in which the floats are fixed. It will be seen that a certain loss of power is involved, as the full force of the engine on the water is only experienced when the float is vertical, and as on entering and leaving the water the power is mainly devoted to respectively lifting and drawing down the vessel. This objection has great force at the moment of starting, or when progress is very slow, as is illustrated by the small power a paddle-steamer evinces when trying to tug a stranded vessel off a sandbank; but when in full progress, the action is less impeded by this circumstance, the water in front of the wheel being depressed, and that abaft being thrown into the form of a wave, so as in each case to offer a nearly vertical resistance to the float. The extent of the immersion much



Ordinary Paddle-wheel.

influences the economy of power, as when the water reaches to the centre of the wheel or above it, it is obvious that the greatest waste must take place. From this it is advantageous to give the wheel as large a diameter as possible, and to place the axis at the highest available point in the vessel.

To overcome the drawbacks to the radial wheel, Elijah Galloway patented, in 1829, the *Feathered Paddle-wheel*, in which the floats are mounted



Feathered Paddle-wheel.

on axes, and are connected by rods with a common centre, which is made to revolve eccentrically to the axis of the paddle-wheel. By this method, the floats are kept, while immersed, at right angles to the surface of the water. So long as the water is smooth, and the immersion constant, the gain is great; consequently, feathered floats are much used in river-steamers; but for ocean-steamers, the liability to derangement, perhaps at a critical period, and the variable depth of immersion, prevent them from becoming favourites.

A recent wheel, called the *Cycloidal*, has the floats divided into smaller sections, in order that the action on the water may reach the maximum of uniformity.

From various causes, the wheel slips somewhat in the water—i. e., revolves more rapidly than the ship makes way. The difference between the two speeds is called the *slip*, and amounts sometimes to one-fifth of the actual speed.

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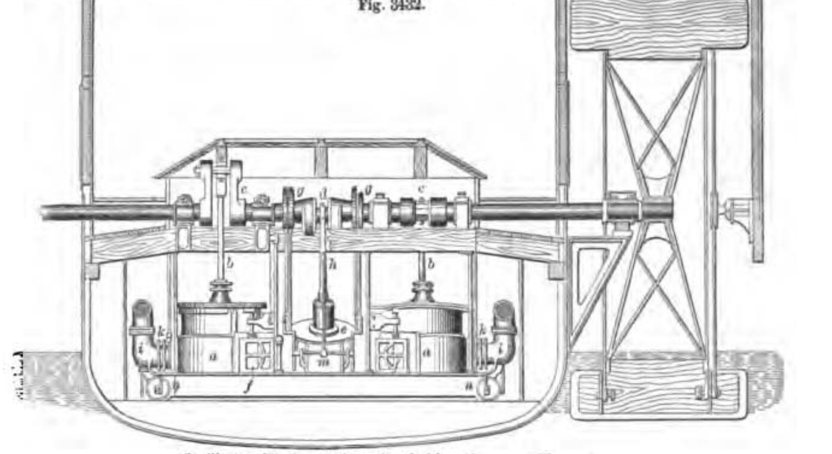
"Thus Time brings all things, one by one, to sight,
And Skill evolves them into perfect light." — LUCRETIUS, Book V.

First Steam Engine.

NEW YORK:
PUBLISHED BY HURD AND HOUGHTON.
Cambridge: The Riverside Press.
1877.

Fig. 3432.



Oscillating Engine on Low-Draft River Steamer (Thames).

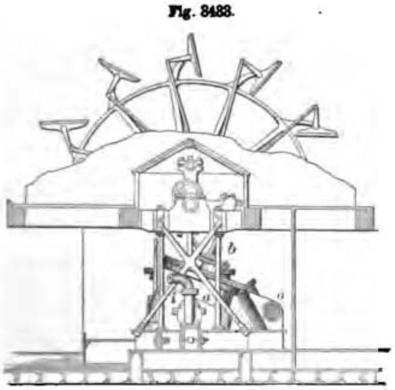
ering paddle-wheels. Fig. 3433 is a side view, showing one cylinder inclined, and the upper portion of the wheel with its floats in their changeable positions. The engines are coupled by an intermediate shaft having a crank which operates one or more air-pumps.

a a are the steam-cylinders; *b b*, the piston-rods, connected immediately with the cranks *c c*; *d*, a crank in the intermediate shaft, working the piston-bucket of the air-pump *e*; *f f* are slide-valves regulating the admission of steam to the cylinders; *g g*, double eccentrics on the intermediate shaft, operating the valves *f f*, enabling a link motion to be employed.

h is a handle by which the engines may be stopped, started, or reversed.

i i are steam-pipes leading to the trunnions *k k*,

Fig. 3433.



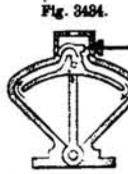
River Steamer Engine (Side View).

on which and on other trunnions connected with the pipe *m* the cylinders oscillate; *n n* are pumps, the pistons of which are attached to the trunnions and worked by the oscillations of the cylinders; *o*, the waste-water pipe from the condenser.

Os'cil-lat-ing-pis'ton Steam-en'gine. A form of steam-engine in which the piston oscillates in a sector-shaped chamber. By means of a slide or other valve the steam is admitted to alternate sides of the piston, which imparts a rotary reciprocation to the rock-shaft.

The engine (Fig. 3435) has a piston planted on an axis and has an oscillation in a vertical plane.

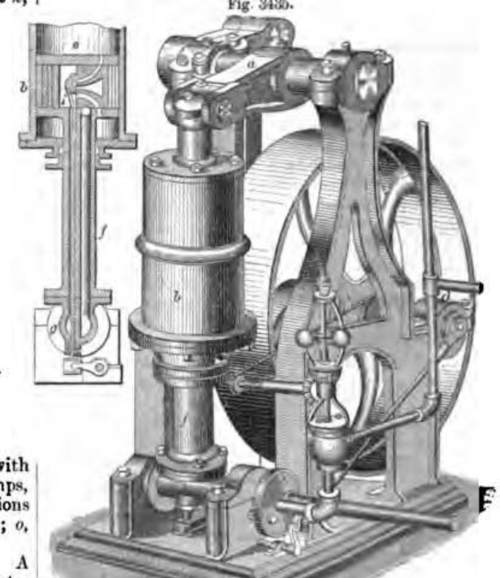
Fig. 3434.



Oscillating-Piston Engine.

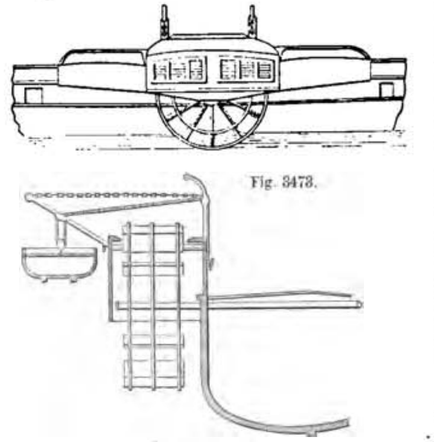
The cylinder *b* is attached to the walking-beam *a*, which oscillates on a rock-shaft, and whose other arm is connected by a pitman with the fly-wheel crank. The piston is at the upper end of a hollow rod *f*, which also oscillates on a hollow rock-shaft *g* divided into two compartments. The piston is hollow, forming a steam-chamber, within which is a slide-valve *i*; it has also

Fig. 3435.



Oscillating-Piston Engine

and lowered down by six men in three minutes. A boat of similar capacity (capable of containing 40 to 50 men) could not be got out, if stowed in the usual position on deck, under twenty minutes, by



Paddle-Box Boat.

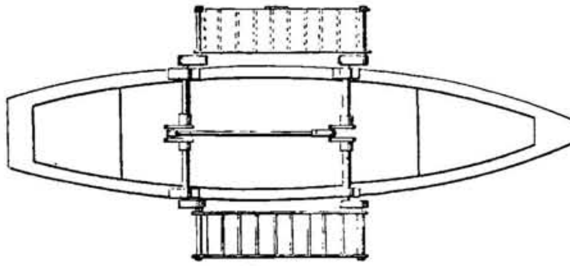
the whole crew; and, in case of fire, probably not at all.

The longitudinal view shows the cabins, cook-houses, etc., before and abaft the wheel-house, similarly covered in.

Pad'dle-hole. (*Hydraulic Engineering.*) A water-channel through which the water passes from the upper pond of a canal to the lock-chamber, or from the latter to the lower pond.

Pad'dle-pro-pel'ler. A form of boat propulsion in which the vertical blades are bolted to a parallel bar and connected to cranks, by whose revolution they are alternately immersed to make the effective stroke and raised clear of the water on the return stroke.

Fig. 3474.



Paddle-Propeller.

Pad'dle-wheel. A water-wheel used in the propulsion of a vessel.

The framework of a paddle-wheel consists of *centers*, *arms*, and *rings*.

The *centers* are *disks* or *bosses*, two or three in number, keyed around the paddle-shaft and having sockets around their rims for the arms.

From each of the *centers* there radiates a set of *arms*, equal in number to the paddles. The *arms* are straight, flat iron bars, so placed as to move edgeways through the water. The outer ends of the arms are T-shaped, and to the cross-bars of each set of arms is riveted an outer *ring* of bar-iron. Inner rings, one or two in number to each set of arms, are riveted to lugs, or projections from the edges of the arms.

The proportions given by Hebert are to make the diameter of the wheel equal to four times the length of the stroke, and the depth of each paddle $\frac{1}{8}$ of the diameter.

The first use of paddle-wheels may have been in the *velocimeters* of the ancients, in which an axis crossed the vessel, projecting over each side, and had paddle-wheels four feet in diameter, which dipped into the water and were rotated by the progress of the vessel. A tooth on the axis worked a train of gearing, so as to drop a ball at every 400th revolution of the paddle-wheel, indicating by sound and count the distance traveled.

Jonathan Hull, in his English patent of December 21, 1736, describes his boat as driven by a fire-engine, meaning a Newcomen atmospheric engine, which rotated "six fanns that turn upon an axis, ... the fanns are brought into and keep a direct motion in the water which forces forward the vessell in which the machine [steam-engine] is placed."

The paddle-wheel has been a favorite subject with inventors, the aim having been to enable it to enter the water without percussion and to leave it without raising a swell.

The greater number of these devices are for feathering the paddles, a subject which belongs to Division 2 (see below).

Some of these devices may be considered under this head, and it may be here stated that the loss of power incident to the obliquity of the blow delivered by the paddle is much exaggerated.

Galloway's patent, 1835, specifies paddles of cycloidal form, which enter the water nearly vertically and avoid concussion. They would probably lift the water when emerging worse than the common float.

Paddle-wheels may be classed under nine different heads: —

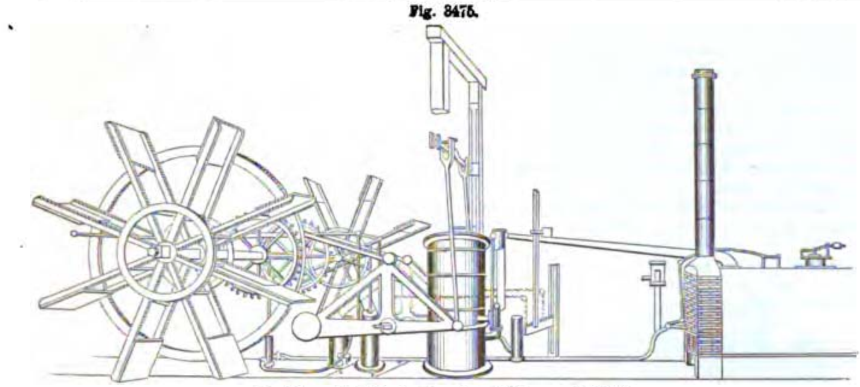
1. Floats fixed on the arms.
2. Feathering floats.
   a. Turning on horizontal axes.
   b. Turning on radial axes
3. Floats sliding radially toward and from the paddle-wheel shaft.
4. Floats attached to traversing chains.
5. Floats attached to cranks.
6. Collapsing paddles.
7. Floats in reciprocating frames.
8. Sculling paddles.
9. Cycloidal paddles.

Fig. 3475 shows the paddle-wheel used by Fulton on the "Clermont" in 1807. This was the first steamboat which can be called a practical success, she having made regular trips between New York and Albany for several years. The paddle-wheel used by Fulton is of substantially the same form as the one now in general use. See Woodcroft's "History of Steam Navigation."

Gemmel's patent, 1837, is rather a duplication than a change of construction. Two pairs of paddle-wheels are employed, the horizontal steam-cylinders having piston-rods proceeding from each end, and having cross-heads from which connecting rods reach to the paddle-wheel shafts.

2. *a.* Buchanan's parallel float-wheel. The floats are attached to horizontal shafts which have their bearings in the radial arms. On the axis of each paddle is an arm from which a rod proceeds to an eccentric on the paddle-wheel shaft. The effect is

Fig. 3475.



Machinery of Fulton's Steamboat "Clermont" (1807).

to keep the floats vertical at all points of their revolution.

In Galloway's patent of 1829 the revolution of the wheel causes an eccentric collar to rotate by the action of arms, and the radius rods cause each paddle to oscillate on its axis so as to enter and leave the water obliquely.

In Oldham's improvement in 1827, the angle of the paddles is constantly varying, being vertical only at the point of greatest submergence, and horizontal at the point of greatest elevation. The change of position is accomplished by the oscillation of the axis of the float, by means of rods, cranks, and an eccentric wheel on the paddle-shaft.

b. Dawson's feathering paddle-wheel (*A*, Fig. 3476), 1814, has floats attached to radial rods which rotate on their axes so as to enter and leave the water obliquely, but present their full surfaces squarely at the point of greatest immersion. The change is effected by affixing on the axis of each paddle two wipers which cross each other at right angles, the wipers coming in contact with inclined planes which cause the axes to oscillate to the extent of 90°.

Head's improvement, 1828, has two leaves to each float; these open so as not to oppose the action in entering and leaving the water, but during immersion form a combined broad float.

3. Leeming's sliding float (*B*), 1835. The arms are grooved and the paddle-boards slip out and in by the action of an eccentric *c* attached to the side of the vessel.

After its effective stroke each paddle is withdrawn nearly vertically.

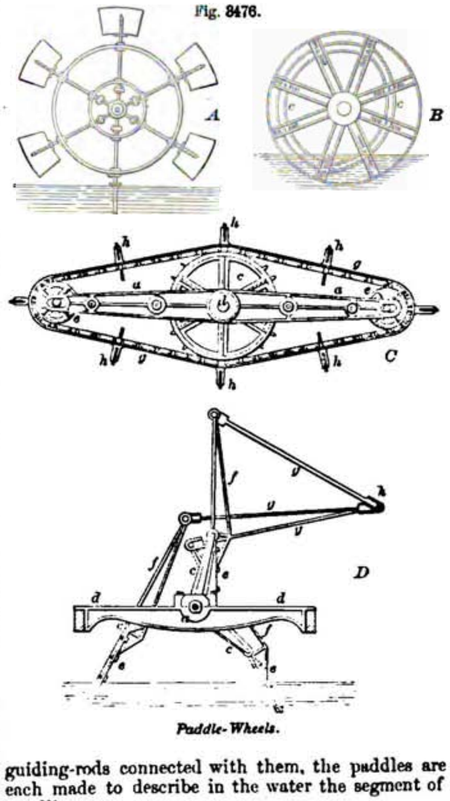
4. Floats attached to endless chains which pass over drums have been used, the intention being to give a direct impulse in the line of the vessel's motion, instead of giving the oblique blow upon the water incident to the ordinary paddle-wheel.

Spurgin's endless-chain propeller (*C*), 1837, passes over three wheels, the larger one being spiked and forming the driving-wheel, while the end wheels are drums which extend the chain and maintain its position; the middle wheel being larger, or having an axis depressed below those of the drums, so as to give a certain obliquity to the floats in entering and emerging.

a a is a cast-iron frame bolted to the side of the vessel; *c* is one of a pair of spike-wheels fixed on the engine-shaft *d*; *e e* are drums running upon the pins or studs on the ends of the frame; *g g* is an endless flat chain passing over the drums *e e*, and over and under the spike-wheel *c*. In order to keep this chain extended, the axes of the drums *e e* move in slots in the frame *a a*, and are keyed up so as to give the requisite tension to the chain. *h h* are the floats, which are carried by iron forks, which are forged in one with the middle links which support them.

5. Stevens's crank-axle paddle (*D*) (English), 1828, has three paddles attached separately to the arms of a three-throw crank, and, by means of radius and guiding-rods connected with them, the paddles are each made to describe in the water the segment of an ellipse.

Fig. 3476.



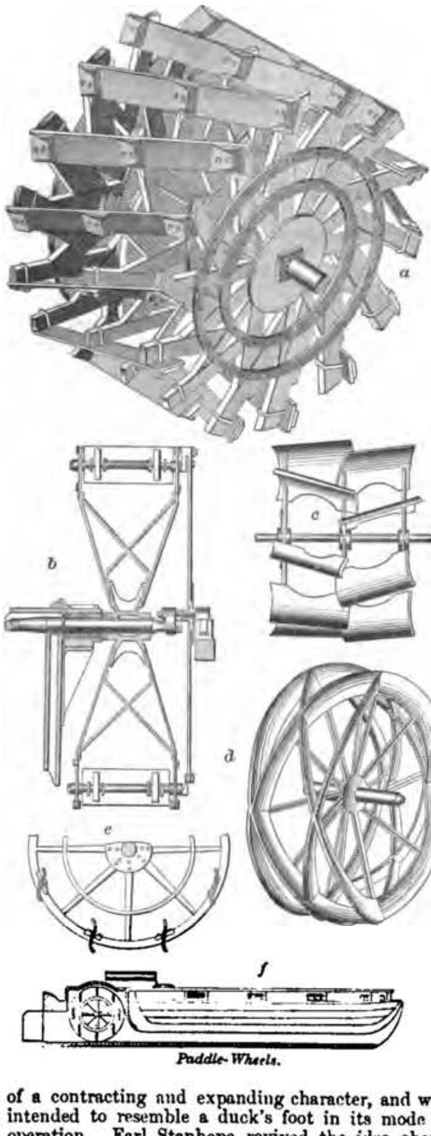
Paddle-Wheels.

a is the axis of a triple crank, the separate arms of which *c c c* move between parallel bars on the side-frame *d d* of the paddle-box. *e e e* are the three paddles connected by the guide-rods *f f f* to the radius-rods *g g g*, the latter working from a fixed beam or center *h*.

6. Nairn's collapsing paddle (English patent, 1828) is allied in principle to the duck's-foot propeller. A number of levers are suspended over the sides of the vessel, extending to any suitable depth. These are made to vibrate by means of the engine, and the feet or paddles on the levers are made to collapse during the non-effective stroke, so as to offer no resistance; but when the effective stroke is made, the float expands, offers its full area to the water, and propels the vessel.

The *duck's-foot* propeller was tried by a Swiss clergyman, named Genevois, about 1737. It was

Fig. 3477



Paddle-Wheels.

of a contracting and expanding character, and was intended to resemble a duck's foot in its mode of operation. Earl Stanhope revived the idea about 1803.

7. Floats in reciprocating frames. A number of vertical floats are arranged in a frame which moves in one set of horizontal guides while making its effective stroke, the paddles being submerged or nearly so. At the end of its stroke it is lifted out of the water, returned along an upper track, dropped down to its work, and then again propelled.

A number of patents have been granted for modifications of this general idea.

8. Perkins's sculling-wheel, patented in England in 1829, has paddles set obliquely on radial arms which are attached to axes sloping toward the stern, so as to make with the axis of the vessel angles of 45° and an angle of 90° with each other. On the extremities of the axis are bevel-wheels, which are both acted upon by an intermediate wheel driven by the engine.

In Fig. 3477, *a* shows a form of paddle-wheel so constructed that the blades descend obliquely into the water, so that an equal amount of blade-surface is submerged at all times and jar avoided. The position of the arms gives the blades such direction as to prevent them from lifting water.

Feathering paddles are of various forms. The object of feathering the floats is to present them to the water at right angles at all times, and to cause them to enter and leave the water edgewise.

In *b*, Fig. 3477, the floats are operated by rods from an eccentric on the crank-shaft. The crank connection between the controlling frame and guard-beam permits the bearing of the controlling frame to change its position in relation to the guard-beam whenever the latter changes its position in relation to the main wheel. In consequence of the diagonal arrangement of said connection, the controlling frame is moved to the least extent by movements of the paddle-guard in vertical and horizontal directions. The arrangement of the paddle-cranks is intended to equally divide the weight of the controlling frame between the paddle-wheel and the paddle-wheel guard.

c, same figure, gives another form of wheel constructed with the same object in view. The floats are curved as well as set diagonally to the shaft.

d is a form of oblique paddle designed to avoid jar.

e has feathering paddles automatically operated by the pressure of water against them.

f shows the paddle within the hull, adapted to canal-boat propulsion.

The paddle-wheels of the "Great Eastern" are 56 feet diameter, 13 feet deep, 30 floats or paddles.

Pad'e-soy. (*Fabric.*) See PADUASOY.

Pad-hook. (*Saddlery.*) A hook on the back-pad to hold up the bearing-rein.

Fig. 3478.

Pad-Hook.

Pad'lock. A lock with a bow to hold on to a staple. Made by Bechar at Nuremberg, A. D. 1540. Dr. Abbott's collection of Egyptian antiquities in New York contains a padlock found in a tomb at Sakkarah. They were also used by the Romans.*

Fig. 3479 is an example of one in which the key, on being inserted, acts first on the tumblers, so as to free the cylinder and to allow a slide to be raised, and it then raises the slide so as to turn the cylinder. The slide-bolt is replaced in its original position by the turning back of the key after the lock has been opened.

Fig. 3480 is a combination padlock having a number of disks which must be brought into coincidence to allow the bolt to be withdrawn from the hasp. The disks are numbered on their peripheries, and

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IN TWO VOLUMES.

VOL. II.

NEW YORK:
D. APPLETON AND COMPANY.
1881.

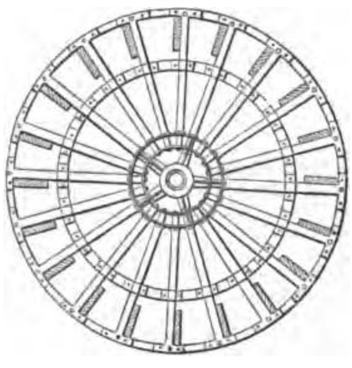
Their ends fall into the forks of the upright forked levers *C*, Figs. 3343 and 3346, the effect of all which is to give a direct motion to the forked levers with their connections that open the mutes *A*, while at the same time each mute is left free to be operated separately or in combination with others. The sub-bass is peculiar to this organ both in its position and the manner in which it is built up. Its register of reeds is placed under the action. Each reed has its heel to the front of the case, so that it can be drawn out under the plinth. Reeds of large size, producing tones of 16 ft. pitch, are placed in very deep cells which afford room for vibration. These cells, with the levers operating the pallets of this set of reeds, are shown in Fig. 3345. The levers are drawn together in front to bring them under an octave of the key-board G. H. B.

ORGANZINE. See SILK-SPINNING MACHINERY.

OVEN. See BREAD AND BISCUIT MACHINERY.

PADDLE-WHEELS * are circular frames carrying floats, buckets, or paddles, so arranged as to propel a vessel by their action upon the water. The commonest form of paddle-wheel is represented in Fig. 3347. It consists of two centres and two sets of concentric wrought-iron rings, which are joined to the centres by a number of radial arms. These two sets are placed at a fixed distance apart on the shaft, and the buckets or floats are attached to the arms near their outer ends, thus connecting the rings. Stays are also run across between the arms, so as to give the whole structure greater firmness. When such a wheel revolves, the floats strike the water and tend to push it back; but the water resists such an action on account of its inertia, and therefore the vessel to which the wheel is attached must move forward.

3347.

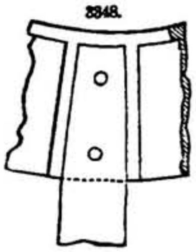


Figs. 3348, 3349, and 3350 represent the usual methods of attaching the arms of paddle-wheels to the centres. In Fig. 3348, the centre consists of a cast-iron plate, to which the arms are bolted in sockets cast therein for the purpose of preventing lateral motion. Fig. 3349 shows a method of inserting the arms in a mortised plate and securing them by keys. In Fig. 3350 the ends of the arms are so shaped as to fit together at the centre, and are riveted to a plate of boiler iron. Fig. 3351 represents the usual mode of securing the arms to the inner ring. A lug is welded on each side of the arm, and through these lugs the arm is riveted to the ring.

The floats for radial paddle-wheels are usually made of pine or elm, 2½ to 3 in. thick. White oak and ⅜-inch boiler iron are also used. After the floats have been attached and the wheel is worked, it is necessary to examine the screws or bolts occasionally, and to draw them up tight, as they are liable to work loose after a while, and then there is danger of the floats being washed off the wheel. The floats are frequently attached by means of hook-bolts, so as to enable the engineer to adjust the depth to which they dip in the water, as a part of the float may drag if not immersed to the right depth; and also a shifting or reefing of the floats may give a better result.

Disengaging Paddle-Wheels.—It is frequently desirable to be able to disconnect one or both paddle-wheels from their shaft, so that they may revolve loosely. Figs. 3352 and 3353 represent a device for this purpose. *A* is the paddle-shaft; *B*, a cast-iron disk keyed thereon; *C*, a wrought-iron strap surrounding the disk, lined with brass; *D*, a brass cushion with a tightening key for producing friction by bringing the cushion in contact with the disk; *F*, the brass lining of the wrought-iron strap, excepting that portion covered by the cushion; *f f*, screws by which the lining is held to the strap. A few blows of a hammer on the key *B* serve to connect or disconnect the shaft.

3348.



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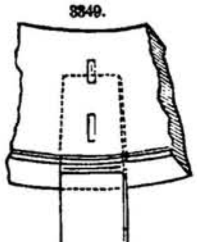

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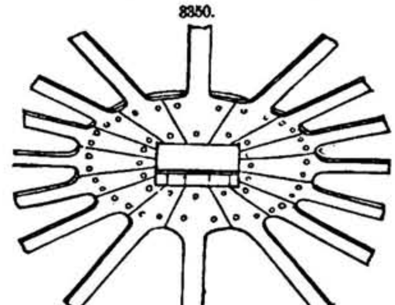

Feathering Paddle-Wheels.—There is a loss of useful effect attending the use of any of the kinds of paddle-wheels described above. This loss arises from the fact that the floats or buckets strike the water obliquely, and therefore do not apply all the power in propelling the vessel, but use up a portion of the same in lifting the vessel when the wheel enters the water, and lose another portion

* Prepared by A. Sorge, Jr., M. E., under supervision of Richard H. Buel.

in raising some of the water when leaving it, and creating a swell. Frequent attempts have been made to obviate this difficulty by making the buckets enter the water edgewise, travel through the water in a vertical position while immersed, and leave it edgewise again. To do this, the buckets must assume different positions with regard to the wheel while revolving, and this action has been

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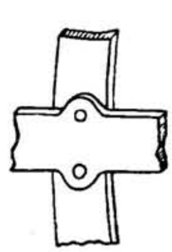

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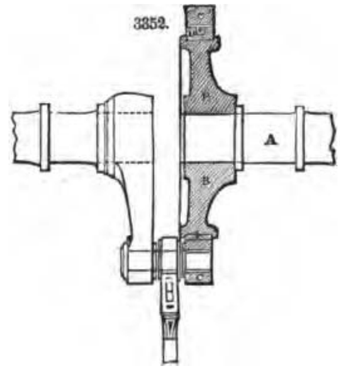

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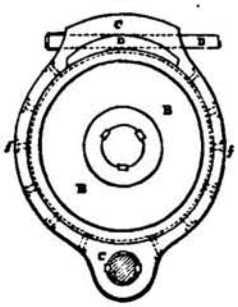
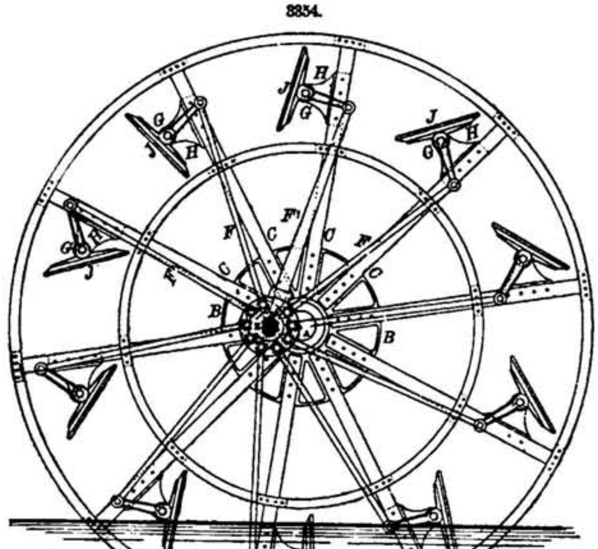


called feathering. Numerous arrangements have been proposed and tried in order to effect this purpose, many of which failed on account of the complication of the parts and their liability to get out of order. We here illustrate a feathering paddle-wheel which has been in successful operation since May, 1877.

Figs. 3354 and 3355 are a side view and section of the feathering paddle-wheel of the steamer Accomac, of the Old Dominion Steamship Company, built at the Morgan Iron Works, New York. It has two sets of rings of 3 × $\frac{5}{8}$-inch iron. The largest diameter of the outside rings is 16 ft. 6 in., of the inner rings 9 ft. 10 in.; clear width between rings, 3 ft. 11$\frac{1}{4}$ in. Two cast-iron centres *B B*, 4 ft. 6 in. diameter and 10 in. bore, have bearings on shaft *A* of 6$\frac{1}{2}$ in. length each, and are spaced 18$\frac{1}{2}$ in. apart in the clear. The rings and centres are joined by two sets of arms *C* (10 in each set), which are riveted inside the rings and on the outside of the centres in recesses cored out for that purpose, as shown in the views. They are 4$\frac{1}{2}$ in. wide and $\frac{7}{8}$ in. thick. The two sets of arms are connected and stayed by means of bent flat iron bars $\frac{5}{8}$ in. thick and 3$\frac{1}{2}$ in. wide, riveted to the arms inside the inner ring, and also to the inner surface of the centres *B B* at recesses cast on for that

3354.



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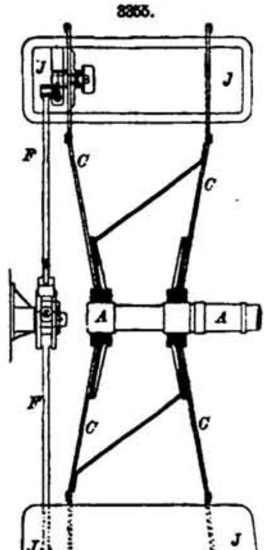

purpose. The centres have two wrought-iron hoops of 1$\frac{1}{4}$ × 1$\frac{1}{4}$-in. iron shrunk around each. There are 10 buckets, *J J*, 30 in. deep by 6 ft. 6 in. wide, which are fastened to the arms by means of brackets *H*, having bearings for the trunnions to turn in, thus holding the buckets, which swing around these trunnions in their relative positions while allowing them to turn or feather. The buckets are attached to the trunnions by the cranks G, which in their turn connect with the eccentric E through the eccentric-rods F ($1\frac{3}{4}$ in. diameter), which can oscillate around pins in E, and also around pins connecting them with the cranks. F' only cannot oscillate in E, and this gives the eccentric a positive motion. The last-named rod is made of $1\frac{1}{2}$-in. flat iron, and tapers from $4\frac{1}{2}$ to $2\frac{1}{2}$ in., being keyed into the eccentric. The eccentric E is placed upon a fixed pin, which is attached to the frame of the paddle-wheel box by means of a casting shown in the section. The trunnions of the buckets are 6 ft. 7 in. from the centre of the wheel. The eyes of the eccentric-rods F, the bore of eccentric E, and the bores of brackets G are lined with lignum-vitæ, and all pins having working surfaces are covered with hard brass. The buckets (10 in number) are made of white oak, and are $2\frac{1}{2}$ in. thick, of the shape shown. The wheel, revolving with the shaft A, turns the buckets; and F' being connected rigidly to the eccentric E, it is revolved also. The centre of E is 11 in. from A and $\frac{1}{2}$ in. below it. This position of the eccentric, and its connection with the buckets, turns the buckets through the medium of the eccentric-rods and cranks, as is shown by the positions of the various buckets in the side view, and thereby produces the action called feathering—i. e., making the buckets enter and leave the water in a nearly vertical position, and guiding them in a direction approximately horizontal while immersed, whereby the loss of effect from oblique action, as well as from the blow upon and the lifting of the water, is avoided. The steamer Accomac, which is propelled by two paddle-wheels of the kind described, measures 145 ft. between perpendiculars, 25 ft. beam, and 9 ft. depth of hold, drawing 4 ft. 9 in. of water. The paddles are immersed to a depth of about 26 in. They are driven by a beam-engine of 32 in. diameter of cylinder and 6 ft. stroke, making from 33 to 37 revolutions, and working with a steam-pressure of 40 lbs., cut off at one-third of the stroke. Its boilers are of the flue and return tubular kind, having 42 sq. ft. of grate surface and about 800 sq. ft. of heating surface. The superintending engineer states that the steamer runs at an average of 13 knots an hour, and that the consumption of coal for a run of 80 miles is 2 gross tons, including the firing up, etc.

Feathering paddle-wheels have been made according to Taylor's patent, in which the buckets are kept vertical throughout the whole revolution, being attached by pins to a ring of the same diameter as the wheel, but placed out of centre vertically by the width of the bucket and held there by friction-rollers.

In 1861 a paddle-wheel without buckets was used, and propelled a small vessel very well. It consisted of a series of plain disks of metal placed at intervals beside each other on the paddle-shaft. The action was evidently dependent merely upon the friction of the water against these disks.

Numerous other kinds of paddle-wheels have been invented at various times. In some of them the buckets are not parallel to the axis of the wheel, but inclined to it, and a certain area of acting surfaces is thus always immersed, making the action more uniform and without shocks. In others the floats are continuous and run obliquely around the wheel, crossing each other at various points. Great advantages have been claimed for each one of these wheels, but none of them have found their way into general use.

Stern Paddle-Wheels.—All the wheels described act at the sides of vessels; but there are also other kinds, such as the stern-wheels which are situated behind the vessel. These are employed on the western rivers of the United States, where the water is shallow, and the channel in which boats can run is often narrow. The construction of the wheels proper for this class is the same as for side-wheels, except that their width is made double that of one side-wheel; and the fundamental difference in the method of propulsion is merely in the application of the power, the form of the steam-engine being different.

Designing of Paddle-Wheels.—In order to find the area of a float of a feathering paddle-wheel, we may use the following formula (see Perry's "Treatise on Steam," page 327): Area of the float $= \frac{R A v^2}{m u (u - v)}$; where u is the velocity of the centre of resistance of the float with reference to the vessel (expressed in knots); v is the actual velocity of the vessel in knots, and therefore $u - v$ is the slip, which may generally be assumed at about 20 per cent. of the speed; m is the mass of a cubic foot of water, $= 2$ for salt water and $= 1.97$ for fresh water; R is a coefficient depending upon the vessel; and A is the area of the greatest immersed cross-section of the vessel. In Rankine's "Ship-Building" we find the same rule, except that A is the so-called augmented surface in his rule, which is found by considerations given in that book, and R is a constant varying from .008 to .011 and upward, according to the vessel. When the area of floats is to be determined for radial wheels, we take (according to Mr. Napier, *Transactions of the Institution of Civil Engineers of Scotland*, 1863-'4) u to be the velocity of the outer edge of the float instead of the centre of resistance, and we must also allow for various immersions of the vessel.

In the above formula the numerator gives the *resistance* of the vessel in pounds. The *centre of resistance*, or centre of pressure, as it is sometimes called, is that point in the float which would produce the same effect if all pressures were united there, at right angles to the radius, as the pressures actually are by being distributed over the whole area. The determination of this point depends upon the so-called *rolling circle*, i. e., a circle of such a radius that every point in it moves backward (while revolving) as fast as the vessel moves ahead. The centre of resistance is always below the middle point, being higher for deep immersions, but never very far from the centre of the figure in well-constructed wheels. Its determination may also be found in Rankine's "Ship-Building." The *slip* of a wheel is the amount of motion lost by the water not being a rigidly fixed body; it is therefore equal to the velocity given in a backward direction to the water, and is the difference between the velocity of the float and that of the vessel.

The theoretical working of a radial paddle-wheel and the effect of oblique action are considered by J. D. Van Buren in an article published in the *Journal of the Franklin Institute*, 3d series, vol. xlix.,

A MANUAL

OF

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BY

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circle in a; join B a, C a; then E a B and E a C will be equal to the angles made by the longer axis with X X and Y Y respectively; and the shorter axis will of course be perpendicular to the longer.*

247. **Feathering Paddle-Wheels** exemplify a class of aggregate combinations in which linkwork is the means of producing the aggregate motion. Each of the paddles is supported by a pair of journals, so as to be capable of turning about a moving axis parallel to the axis of the paddle-wheel, while its position relatively to that moving axis is regulated by means of a lever and rod connecting it with another fixed axis. Thus, in fig. 199, A is the axis of the paddle-wheel; K the other fixed axis, or eccentric-axis; B, E, N, C, P, M, D the axis of a paddle at various points of its

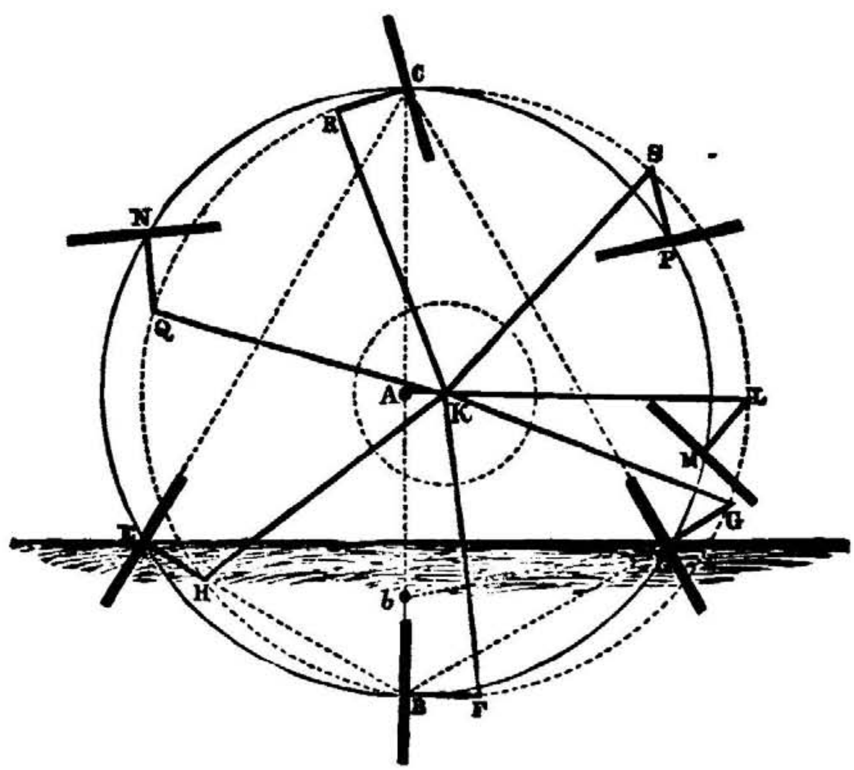

Fig. 199.

revolution round the axis A of the wheel; B F, E H, N Q, C R, P S, M L, D G, the *stem-lever* of the paddle in various positions; K F, K H, K Q, K R, K S, K L, K G, various positions of the guide-rod which connects the stem-lever with the eccentric-axis.

When the end of the paddle-shaft *overhangs*, and has no outside

* The oblique-angled trammel is believed to be the invention of Mr. Edmund Hunt.

bearing, the eccentric-axis may be occupied by a pin fixed to the paddle-box framing; but if the paddle-shaft has an outside as well as an inside bearing, the inner ends of the guide-rods are attached to an *eccentric collar*, large enough to contain the paddle-shaft and its bearing within it, and represented by the small dotted circle that is described about K. One of the rods, called the *driving-rod*, is rigidly fixed to the collar, in order to make it rotate about the axis K; the remainder of the rods are jointed to the collar with pins.

The object of the combination is to make the paddles, so long as they are immersed, move as nearly as possible edgewise relatively to the water in the paddle-race. The paddle-race is assumed to be a uniform current moving horizontally, relatively to the axis A, with a velocity equal to that with which the axes B, &c., of the paddle-journals revolve round A. Let E be the position of a paddle-journal axis at any given instant; conceive the velocity of the point E in its revolution round A to be resolved into two components,—a normal component perpendicular, and a tangential component parallel, to the face of the paddle. Conceive the velocity of the particles of water in the paddle-race to be resolved in the same way. Then, in order that the paddle may move as nearly as possible edgewise relatively to the water, the normal components of the velocities of the journal E and of the particles of water should be identical.

Let B be the lowest point of the circle described by the paddle-journal axes; that is, let A B be vertical. Draw the chord E B. Then it is evident that the component velocities of the points B and E along E B are identical. But the velocity of B is identical in amount and direction with that of the water in the paddle-race. Therefore the face of a paddle at E should be normal to the chord E B, or as nearly so as possible. Another way of stating the same principle is to say that a tangent, E C, to the face of the paddle should pass through the *highest point*, C, of the circle described by the paddle-journal axes, C A B being the vertical diameter of that circle.

It is impossible to fulfil this condition exactly by means of the combination shown in the figure; but it is fulfilled with an approximation sufficient for practical purposes, so long as the paddles are in the water, by means of the following construction:—Let D and E be the two points where the circle described by the paddle-journals cuts the surface of the water. From the uppermost point, C, of that circle draw the straight lines C E, C D, to represent tangents to the face of a paddle at the instant when its journals are entering and leaving the water. Draw also the vertical diameter C A B, to represent a tangent to the face of a paddle at the instant when it is most deeply immersed. Then draw the stem-lever projecting from the paddle in its three positions, D G, B F, E H. In the figure, that lever is drawn at right angles to the face of the paddle; but the angle at which it is placed is to a certain extent arbitrary, though it seldom deviates much from a right angle. The length of the stem-lever is a matter of convenience: it is usually about $\frac{3}{5}$ of the depth of the face of a paddle. Then, by plane geometry, find the centre, K, of the circle traversing the three points, G, F, and H; K will mark the proper position for the eccentric-axis; and a circle described about K, with the radius K F, will traverse all the positions of the joints of the stem-levers.

From the time of entering to the time of leaving the water, paddles fitted with this feathering gear move almost exactly as required by the theory; but their motion when above the surface of the water is very different, as the figure indicates.

To find whether, and to what extent, it may be necessary to notch the edges of the paddles, in order to prevent them from touching the guide-rods, produce A K till it cuts the circle G F H in L; from the point L lay off the length, L M, of the stem-lever to the circle D B E; and draw a transverse section of a paddle with the axis of its journals at M, its stem-lever in the position M L, and its guide-rod in the position L K. This will show the position of the parts when the guide-rod approaches most closely to the paddle.

Some engineers prefer to treat the paddle-race as undergoing a gradual acceleration from the point where the paddle enters the water to the point of deepest immersion. The following is the consequent modification in the process of designing the gear:—Let the final velocity of the paddle-race be, as before, equal to that of the point B in the wheel, and let the initial velocity be equal to that of the point *b*, at the end of a shorter vertical radius, A *b*. Let D be the axis of a paddle-journal in the act of entering the water, and E the same axis in the act of leaving the water. Join *b* D and B E; draw the face of the paddle at D normal to D *b*, the face of the paddle at B vertical, as before, and the face of the paddle at E normal to E B. Then draw the stem-lever in its three positions, making a convenient constant angle with the paddle-face; and find the centre of a circle traversing the three positions of the end of the stem-lever; that centre will, as before, mark the proper position for the eccentric-axis.

248. **Spherical Epitrochoidal Paths—Z-Crank.**—A point rigidly attached to a cone which rolls on another cone describes a *spherical epitrochoid*, situated in a spherical surface whose centre is at the common apex of the two cones. This sort of aggregate motion is illustrated by Mr. Edmund Hunt's Z-crank.

In fig. 200, A A is a rotating shaft, carrying at B, B, two crank-arms, which project in opposite directions, and are connected with each other by means of a cylindrical crank-pin, B B. The shaft,

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ults of Recent Researches on the efficiency of screw-propel- ı summarized by S. W. Barnaby, in a paper read before section G of gineering Congress, Chicago, 1893. He states that the following gen- nciples have been established:

here is a definite amount of real slip at which, and at which only, um efficiency can be obtained with a screw of any given type, and ount varies with the pitch-ratio. The slip-ratio proper to a given f pitch to diameter has been discovered and tabulated for a screw ındard type, as below (see table on page 1012):

crews of large pitch-ratio, besides being less efficient in themselves, the resistance of the hull by an amount bearing some proportion to istance from it, and to the amount of rotation left in the race.

he best pitch-ratio lies probably between 1.1 and 1.5.

'he fuller the lines of the vessel, the less the pitch-ratio should be.

oarse-pitched screws should be placed further from the stern than ched ones.

Apparent negative slip is a natural result of abnormal proportions of lers.

'hree blades are to be preferred for high-speed vessels, but when the er is unduly restricted, four or even more may be advantageously yed.

n efficient form of blade is an ellipse having a minor axis equal to nths the major axis.

'he pitch of wide-bladed screws should increase from forward to aft, uniform pitch gives satisfactory results when the blades are narrow, e amount of the pitch variation should be a function of the width of ade.

A considerable inclination of screw-shaft produces vibration, and with handed twin-screws turning outwards, if the shafts are inclined at should be upwards and outwards from the propellers.

results of experiments with screw-propellers, see F. C. Marshall, Proc. I. E. 1881; R. E. Froude, Trans. Institution of Naval Architects, 1886; Calvert, Trans. Institution of Naval Architects 1887; and S. W. Bar- Proc. Inst. Civil Eng'rs 1890, vol. cii.

of the most important results deduced from experiments on model s is that they appear to have practically equal efficiencies throughout range both in pitch-ratio and in surface-ratio; so that great latitude to the designer in regard to the form of the propeller. Another im- nt feature is that, although these experiments are not a direct guide to lection of the most efficient propeller for a particular ship, they sup- e means of analyzing the performances of screws fitted to vessels, and is indirectly determining what are likely to be the best dimensions of for a vessel of a class whose results are known. Thus a great ad- has been made on the old method of trial upon the ship itself, which he origin of almost every conceivable erroneous view respecting the -propeller. (Proc. Inst. M. E., July, 1891.)

THE PADDLE-WHEEL.

ddle-wheels with Radial Floats. (Seaton's Marine En- ring.)—The effective diameter of a radial wheel is usually taken from entres of opposite floats; but it is difficult to say what is absolutely diameter, as much depends on the form of float, the amount of dip, he waves set in motion by the wheel. The slip of a radial wheel is 15 to 30 per cent, depending on the size of float.

$$\text{Area of one float} = \frac{\text{I.H.P.}}{D} \times C.$$

s the effective diameter in feet, and C is a multiplier, varying from ı tugs to 0.175 in fast-running light steamers.

breadth of the float is usually about ¼ its length, and its thickness ⅛ its breadth. The number of floats varies directly with the diam- and there should be one float for every foot of diameter.

r a discussion of the action of the radial wheel, see Thurston, Manual Steam-engine, part ii., p, 182.)

athering Paddle-wheels. (Seaton.)—The diameter of a ering-wheel is found as follows: The amount of slip varies from 12 to r cent, although when the floats are small or the resistance great it is as high as 25 per cent; a well-designed wheel on a well-formed ship should not exceed 15 per cent under ordinary circumstances.

If K is the speed of the ship in knots, S the percentage of slip, and R the revolutions per minute,

$$\text{Diameter of wheel at centres} = \frac{K(100 + S)}{3.14 \times R}.$$

The diameter, however, must be such as will suit the structure of the ship, so that a modification may be necessary on this account, and the revolutions altered to suit it.

The diameter will also depend on the amount of "dip" or immersion of float.

When a ship is working always in smooth water the immersion of the top edge should not exceed 1/8 the breadth of the float; and for general service at sea an immersion of 1/2 the breadth of the float is sufficient. If the ship is intended to carry cargo, the immersion when light need not be more than 2 or 3 inches, and should not be more than the breadth of float when at the deepest draught; indeed, the efficiency of the wheel falls off rapidly with the immersion of the wheel.

$$\text{Area of one float} = \frac{\text{I.H.P.}}{D} \times C.$$

C is a multiplier, varying from 0.3 to 0.35; D is the diameter of the wheel to the float centres, in feet.

The number of floats $= \frac{1}{2}(D + 2)$.
The breadth of the float $=$ 0.35 $\times$ the length.
The thickness of floats $=$ 1/12 the breadth.
Diameter of gudgeons $=$ thickness of float.

Seaton and Rounthwaite's Pocket-book gives:

$$\text{Number of floats} = \frac{60}{\sqrt[3]{R}},$$

where R is number of revolutions per minute.

$$\text{Area of one float (in square feet)} = \frac{\text{I.H.P.} \times 33000 \times K}{N \times (D \times R)^3},$$

where N = number of floats in one wheel.

For vessels plying always in smooth water $K = 1200$. For sea-going steamers $K = 1400$. For tugs and such craft as require to stop and start frequently in a tide-way $K = 1600$.

It will be quite accurate enough if the last four figures of the cube $(D \times R)^3$ be taken as ciphers.

For illustrated description of the feathering paddle-wheel see Seaton's Marine Engineering, or Seaton and Rounthwaite's Pocket-book. The diameter of a feathering-wheel is about one half that of a radial wheel for equal efficiency. (Thurston.)

Efficiency of Paddle-wheels.—Computations by Prof. Thurston of the efficiency of propulsion by paddle-wheels give for light river steamers with ratio of velocity of the vessel, v, to velocity of the paddle-float at centre of pressure, V, or $\frac{v}{V}, = \frac{3}{4}$, with a dip = 3/20 radius of the wheel, and a slip of 25 per cent, an efficiency of .714; and for ocean steamers with the same slip and ratio of $\frac{v}{V}$, and a dip = 1/2 radius, an efficiency of .685.

JET-PROPULSION.

Numerous experiments have been made in driving a vessel by the reaction of a jet of water pumped through an orifice in the stern, but they have all resulted in commercial failure. Two jet-propulsion steamers, the "Waterwitch," 1100 tons, and the "Squirt," a small torpedo-boat, were built by the British Government. The former was tried in 1867, and gave an efficiency of apparatus of only 18 per cent. The latter gave a speed of 12 knots, as against 17 knots attained by a sister-ship having a screw and equal steam-power. The mathematical theory of the efficiency of the jet was discussed by Rankine in *The Engineer*, Jan. 11, 1867, and he showed that the greater the quantity of water operated on by a jet-propeller, the greater

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is a measure of the efficiency of propulsion of that vessel when considered in conjunction with the true slip. It should never be construed to be a measure of the efficiency of propulsion if considered only by itself. Experience has shown that a very low apparent slip by itself may be an indication of poor efficiency; in that case, it will be combined with a high true slip. A low apparent slip coupled with a low true slip, however, indicates a high efficiency, while a high apparent slip and high true slip indicate a poor efficiency for the existing conditions. Likewise, a high apparent slip and a low true slip indicate a poor efficiency of propulsion for the existing conditions. This fact is illustrated by considering a vessel moored to the dock, with the engine working ahead. As the vessel does not advance at all, the apparent slip is 100 per cent.; the true slip, as measured by the difference in velocity of the stream projected by the propeller and the speed of the water fed to it, may be extremely low, say 1 per cent. Then, for this case, the efficiency of propulsion, if perfection is taken as 1, is $1 - 1 = 0$; while the efficiency of the propeller is $1 - .01 = .99$.

19. It is customary among writers on marine propulsion to refer to apparent slip simply as slip; when the true slip is meant, it is usual to qualify the term slip by prefixing the word true or real, that is, to call it distinctly the true slip or the real slip.

PADDLE WHEELS

DEFINITIONS

20. The **paddle wheel**, in its simplest form, consists of two rings, concentric with the axis of the shaft and lying in planes perpendicular to it, that are secured, by arms, to a hub keyed to the shaft. At the outer edges of the rings, and placed between them, are the **buckets** (sometimes called **floats**), which are either flat wooden boards, generally elm, or iron plates; they are situated at equal distances apart, in planes passing through the axis of the shaft. A paddle wheel with the buckets placed thus is known as a *radial wheel*. The wheel, or wheels, is attached to the vessel in such a position that the lower part is immersed in water to a certain depth, which is usually spoken of as the **dip** of the wheel. The vertical distance from the inner edge of the buckets to the surface of the water, is called the **immersion of the buckets.**

SLIP OF PADDLE WHEEL

21. In order to find the velocity at which a stream of water is projected by a paddle wheel, it is necessary to first find that point of the wheel at which its whole action on the water may be assumed to be concentrated. This point is known as the **center of pressure,** often called the **center of action** of the wheel; and twice the distance of this point from.the outer edge of the buckets subtracted from the diameter of the wheel (the diameter to be measured from outer edge to outer edge of buckets) constitutes the **effective diameter** of the wheel.

The effective diameter may be determined approximately by the following rule:

Rule.—*Multiply one-third the mean depth of the buckets wholly immersed by the number of buckets so immersed. To this product, add the product of one-third the mean depth of the buckets partly immersed and their number. Divide the sum of the two products by the number of the buckets partly and wholly immersed. The quotient will be the distance of the center ot pressure from the outer edge of the buckets. The effective diameter can then be found by subtracting twice the distance of the center of pressure from the outer edge of the buckets from the outside diameter of the wheel.*

Or,
$$D_e = D - 2 \times \frac{a\,b + c\,d}{3(b + d)}$$

where P = distance of center of pressure from outer edge of buckets, in inches;

a = mean depth of buckets wholly immersed, in inches;

b = number of buckets wholly immersed;
c = mean depth of buckets, partly immersed, in inches;
d = number of buckets partly immersed;
D = diameter of wheel, measured over outer edge of buckets;
D_e = effective diameter.

To find the mean depth of the buckets, and also the number of buckets wholly and partly immersed, draw the wheel to any convenient scale, taking care to draw the buckets in their true positions. Also, draw a line representing the surface of the water, at a distance from the outer edge of the lowest bucket equal to the dip. Then the number of buckets wholly and partly immersed will be seen at a glance. To find the mean depth of the buckets, measure the depth of each bucket wholly immersed (not the depth to which each bucket is immersed) to the same scale the wheel was drawn, and perpendicular to the surface of the water. Add the depths of the different buckets together, and divide the sum by the number of buckets wholly immersed. For those partly immersed, which hardly ever will be more than two, measure the perpendicular distance between the lower edge of the bucket and the surface of the water. Add the distances together, and divide by the number of buckets.

EXAMPLE.—A paddle wheel 36 feet in diameter has, at a certain dip, seven buckets of a mean depth of 24 inches wholly immersed, and one bucket immersed to a depth of 15 inches; find the effective diameter of the wheel.

SOLUTION.—Applying the rule,

$$D_e = 36 \times 12 - 2 \times \frac{24 \times 7 + 15 \times 1}{3(7+1)} = 416.75 \text{ in. Ans.}$$

Having determined the effective diameter, to determine the theoretical velocity of the stream projected by the wheel, find the velocity of a point on the circle having a diameter equal to the effective diameter of the wheel, expressing its velocity in the same terms in which the speed of the vessel is expressed. For example, taking the wheel in the above example, its circumference will be 3.1416 × 416.75 = 1,309.26

inches. Assuming the revolutions to be 20 per minute, the speed of a point on the effective diameter circle will be, in feet per second, $\frac{1{,}309.26 \times 20}{12 \times 60} = 36.37$ feet. This is, theoretically, the velocity of the stream projected by the wheel; and, knowing the velocity of the vessel, the slip may be found by rule I or rule II, Art. **17**.

RADIAL PADDLE WHEEL

22. In Fig. 1, a **radial paddle wheel** is shown in diagrammatic form, where A represents the shaft; B, B_1, B_2,

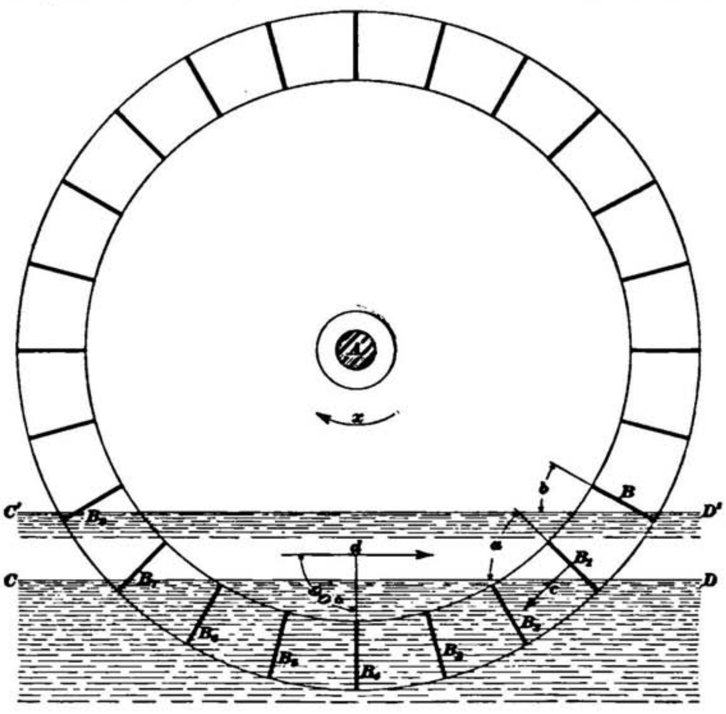

FIG. 1

etc. represent the buckets. Assume the wheel to revolve in the direction of the arrow x; also, assume the line CD to represent the surface of the water. Then, the direction in which the vessel moves, which is evidently parallel to the surface of the water, is shown by the arrow *d*. It will be seen that the bucket B_1, just entering the water, enters at an angle, shown by the arc *a*, with the surface. This angle is known as the **angle of incidence.** The effect of this is that the bucket, instead of driving a body of water straight astern, drives it in a direction perpendicular to the surface of the bucket, as indicated by the arrow *c*; in other words, the bucket depresses the water. The power consumed in depressing the water is wasted. Evidently, the stream of water projected by the propelling instrument will have the maximum propelling effect if projected straight astern, in a direction parallel to the surface of the water. This is proved by the following simple experiment: Place some heavy weight, weighing, say, about 100 pounds, on the floor. Try to slide it along the floor by pushing against the end of a board placed against the weight, and held at an angle of about 45° with the floor. The chances are that it will not be possible to move it. Depress that end of the board against which the push is exerted, and push just as hard as in the first place. It will now be found possible to move the weight, and it will also be found that the more the free end of the board is depressed, the less will be the power required to move the weight. This proves that the nearer the direction of a force is to the direction in which a weight (as the vessel) is to be moved, the less will be the amount of power required. From this, it follows that the nearer the angle of incidence is to 90°, the more efficiently will the power be applied. By reference to Fig. 1, it will be seen that it is not alone through the action of the bucket B_1 that power is lost, but also that a further loss of power is due to the oblique action of the buckets B_2 and B_3. The only bucket that is acting at its maximum efficiency is B_4, the surface of which is perpendicular to the direction in which the vessel moves. It will be observed that the buckets B_5, B_6, and B_7 tend to elevate a body of water; this causes a loss of power equal to that caused by the action of the buckets

B_1, B_2, and B_3. The sum of the two losses is called the *loss of effect due to oblique action of the buckets*, and is a defect inseparable from the employment of a radial paddle wheel.

Assume the vessel to be loaded until the surface of the water is at $C' D'$. It will be seen that the angle of incidence b is less than it was previously; hence, more power will be uselessly expended. From the foregoing explanations, the following conclusion is drawn: The greater the dip of a paddle wheel, the greater will be the loss of power due to oblique action of the buckets.

FEATHERING PADDLE WHEEL

23. In order to prevent the loss of power incidental to the use of radial buckets, a paddle wheel in which, by a suitable mechanism, the buckets are forced to enter the water perpendicularly, or nearly so, is often used. Such a wheel, which is known as a **feathering paddle wheel,** is shown in Fig. 2. The buckets B, B_1, . . . B_6, turn on pins fixed in brackets a attached to the arms A of the wheel; they are free to move on axes parallel to the axis of the shaft. To the outboard end of each bucket, a lever L is rigidly attached; in order to control the buckets, the extremity of each lever is connected to the eccentric strap F by means of a radius rod r, which is pivoted to the strap as well as to the lever. An eccentric pin c is placed at a distance d ahead of the shaft. The eccentric pin is stationary, but the eccentric strap is free to revolve on the pin. The pin is supported by means of the bracket E, which, in turn, is bolted to the sponson beam G. To give motion to the eccentric strap, it is attached to one of the bucket levers by means of the kingrod H. The kingrod, which is rigidly fastened to the eccentric strap, is pivoted to the bucket lever. As the wheel revolves, each bucket in its turn, on entering the water, assumes the position in which the bucket B is shown, and, in passing around with the wheel, assumes the positions of the buckets B_1, B_2, . . . B_6.

It will be seen at a glance that, for wheels of equal diameter and equal dip, the angle of incidence is much larger

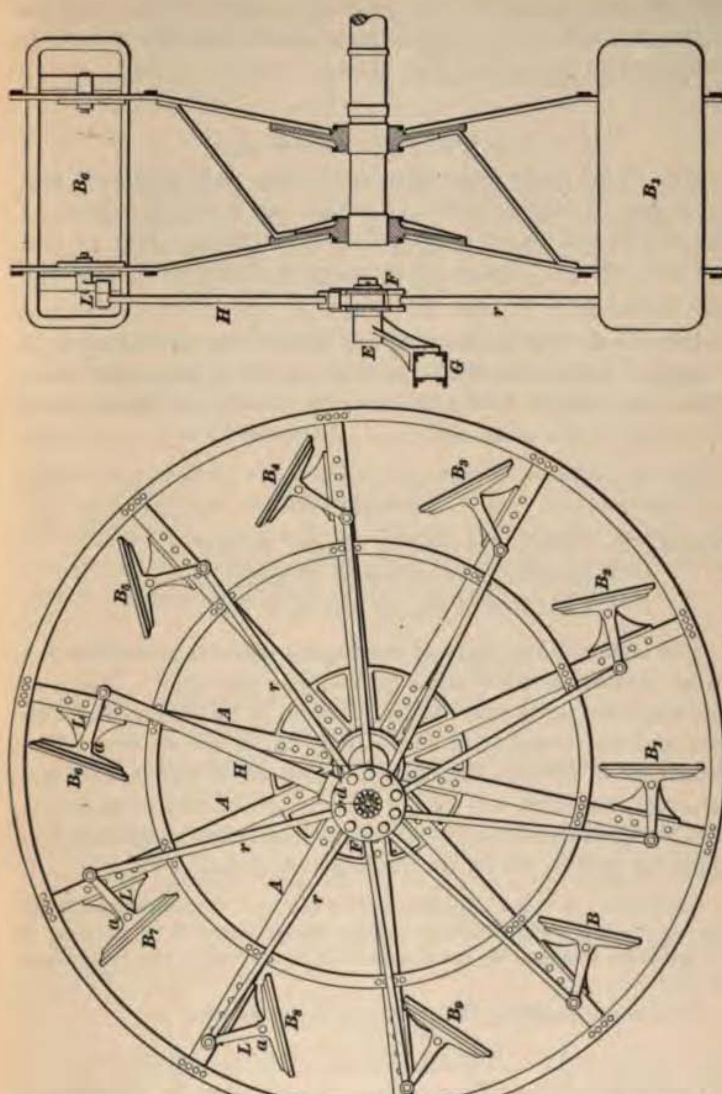

FIG. 2

with the feathering than with the radial paddle wheel. Hence, a larger proportion of the power applied to the wheel is expended in propelling the vessel.

ROLLING CIRCLE

24. The circle concentric with the paddle wheel, any point on the circumference of which has a velocity equal to the velocity of the vessel is called the **rolling circle of the paddle wheel.** Its diameter may be found by the following rule:

Rule.—*To find the diameter, in feet, of the rolling circle of a paddle wheel, divide the distance moved by the vessel in a given time, in feet, by 3.1416 times the number of revolutions of the wheel in the same time.*

Or, $$D = \frac{S}{3.1416\,R}$$

where S = distance moved by vessel, in feet;
R = number of revolutions of wheel;
D = diameter of rolling circle, in feet.

The term rolling circle of the paddle wheel is an expression of no particular value, although considerably used. The true and apparent slips may be determined if the effective diameter and the diameter of the rolling circle are known. The difference in the two diameters, expressed in per cent. of the effective diameter, will be the percentage of true or apparent slip, and will be found to be the same, all data remaining the same, as that found by the rules given in Art. **17.**

EXAMPLE.—A vessel advances 1,570.8 feet in 1 minute, as shown by the log, during which time the paddle wheels make 25 revolutions; if the effective diameter of the wheels is 25 feet, what is the percentage of slip?

SOLUTION.—Applying the rule given in this article,

$$D = \frac{1{,}570.8}{3.1416 \times 25} = 20 \text{ ft.},$$

the diameter of the rolling circle. The difference in diameters is $25 - 20 = 5$ ft.; and this, in per cent. of the effective diameter equals $\frac{5}{25} = .2 = 20$ per cent., the apparent slip. Ans.

The velocity of the stream projected by the wheels is 25 × 25 × 3.1416 = 1,963.5 ft. Substituting values in rule II, Art. **17**,

$$S_a = \frac{1,963.5 - 1,570.8}{1,963.5} = .2 = 20 \text{ per cent., the same as above.}$$

SIZE OF PADDLE WHEELS

25. Diameter.—The effective diameter of a paddle wheel is found by the rule below. In order to apply this rule, an apparent slip has to be assumed, and the velocity of the ship in relation to the water it floats in, as well as the number of revolutions, has to be known. The apparent slip for a radial wheel varies from 15 to 30 per cent., the lower value occurring with buckets of ample area, and averages about 25 per cent.; the apparent slip of a feathering paddle wheel averages 15 per cent.

Rule.—*To find the effective diameter of a paddle wheel, in feet, multiply the difference between 1 and the percentage of apparent slip, expressed decimally, by the proposed number of revolutions per minute and by 3.1416. Divide the speed of the ship per minute in relation to the water by this product.*

Or,
$$D_e = \frac{V_s}{(1 - S_a)\,3.1416\,N}$$

where D_e = effective diameter, in feet;
S_a = apparent slip, in per cent.;
V_s = velocity of ship, in feet per minute;
N = number of revolutions per minute.

Example.—A vessel is to make 10 statute miles per hour through the water when the wheels make 30 revolutions per minute; assuming a slip of 25 per cent., what should be the effective diameter of the paddle wheels?

Solution.— 10 statute mi. per hr. $= \frac{10 \times 5,280}{60} = 880$ ft. per min. Applying the rule given,

$$D_e = \frac{880}{(1 - .25) \times 3.1416 \times 30} = 12.45 \text{ ft. Ans.}$$

26. Area and Number of Buckets.—For radial and feathering paddle wheels, when the ship is a side-wheel steamer, Seaton recommends that the area, in square feet, of one bucket and the number be as follows:

Rule.—*To find the area of one bucket for the paddle wheels of a side-wheel steamer, divide the indicated horsepower of the propelling machinery by the effective diameter of the wheel, in feet. For a radial paddle wheel, multiply the quotient by .25 for slow boats, and by .175 for fast-running light steamers, choosing a value between the two given as judgment indicates it should be varied. For a feathering paddle wheel, multiply the quotient by .32. For a radial paddle wheel there should be one bucket for each foot of effective diameter; to find the number of buckets for a feathering paddle wheel, add 2 to the effective diameter, in feet, and divide the sum by 2.*

Or,
$$A = \frac{\text{I. H. P.} \times C}{D_e}$$
$$n = D_e \text{ for radial paddle wheels}$$
$$n = \frac{D_e + 2}{2} \text{ for feathering paddle wheels}$$

where A = area of one bucket, in square feet;
I. H. P = indicated horsepower;
C = a constant varying between .175 and .25 for radial wheels, and taken as .32 for feathering wheels;
D_e = effective diameter, in feet;
n = number of buckets.

If the side wheels are driven by separate engines, their combined horsepower is to be used. For a stern-wheel steamer, the area of the bucket may be about twice that given by the rule. For side-wheel steamers, the depth of the buckets is usually made about one-fourth their width.

Example.—Find the area of each bucket and their number for a side-wheel steamer fitted with feathering paddle wheels 25 feet in effective diameter, each wheel being driven by a separate engine of 500 indicated horsepower.

Solution.—Applying the rule given,
$$A = \frac{(500 + 500) \times .32}{25} = 12.8 \text{ sq. ft.}$$
and
$$n = \frac{25 + 2}{2} = 13.5 = 14. \text{ Ans.}$$

THE

MARINE STEAM ENGINE

A TREATISE FOR ENGINEERING STUDENTS
YOUNG ENGINEERS, AND OFFICERS OF THE ROYAL NAVY
AND MERCANTILE MARINE

BY THE LATE

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CHAPTER XXIV.

PADDLE-WHEELS.

Radial paddle-wheel.—The simplest form of paddle-wheel is generally known as the common or radial paddle-wheel. In this wheel the floats are bolted direct to the arms of the wheel, and consequently the pressure they produce on the water is always perpendicular to the radius, and the only float that produces a direct sternward reaction is the one at the bottom of the wheel, all the others having a vertical component tending to raise or depress the vessel, which is wasted so far as propulsion is concerned.

Width of floats.—The extreme width of the floats should not exceed one-half the width of the vessel, so that the combined width of the two paddle-wheels should not be greater than the width of the ship. In sea-going steamers the width of float generally does not exceed one-third the width of vessel. In still water the greater the width of float the more effective the wheel, as the required area of race can be obtained with less immersion, and the loss from oblique action is thereby reduced. This condition, however, is limited by the practical difficulties involved in supporting the overhanging end of the paddle-shaft. In rough weather extreme width would be objectionable from many causes.

Immersion of wheels.—The depth of immersion of paddle-wheels is practically limited by the draught of water of the vessel, as it is evidently undesirable to allow the lower edge of the propeller to be below the keel. The immersion of the wheels must also depend on their diameter, for if the floats act too obliquely on entering and leaving the water, a large proportion of the power would be wasted in producing vertical reactions. As an extreme case, we may point out that a radial paddle-wheel immersed to its centre would be of no value as a propeller.

In general the greatest immersion of a paddle-wheel should not exceed one-half the radius, or one-fourth the diameter of the wheel. When sea-going steamers were used for long voyages, the immersion at starting was about one-half the radius, and the mean draught for the voyage about one-third the radius of the wheel.

For effective working, the tops of the floats, when in their lowest position, should always be some distance below the surface of the water. In large sea-going paddle steamers the top of the lowest float was usually about 18 to 20 inches below the surface, at mean draught; in smaller vessels from 12 to 15 inches. In river steamers the immersion is generally much less, say from 3 to 6 inches; but these boats always work in smooth water, and their draught is practically constant. In sea-going steamers the immersion of the floats at their lightest draught shoud not be less than 6 inches.

Number and pitch of floats.—In radial paddle-wheels the numbe of floats is generally made equal to the number of feet in the diameter of the wheel, which practically sets them at about 3 feet apart from each other. In some fast ships, to reduce vibration, they have been set closer than this, or from 2 to 2½ feet apart. If the floats be set too closely together the water will not escape with sufficient freedom from between them, whilst if too far apart the vibratory action will be excessive. The number and pitch of floats should be so arranged that there will always be at least three floats immersed at the same time.

Reefing paddle-wheels.—The floats are secured to the radial arms of the paddle-wheels by hook-bolts, in such a manner that if the draught of the vessel be increased, the floats may be readily unshipped and secured in other positions nearer the centre of the wheels. This operation is usually called *reefing the paddle-wheels*, and is equivalent to reducing the effective diameter of the wheel and the immersion of the floats, and thereby diminishing the loss from oblique action. Reefing is desirable when by increased draught it is found that the wheels cannot be driven fast enough to utilise all the steam generated in the boilers. This operation, by decreasing the resistance, enables all the steam generated to be used, and the piston speed increased, with a consequent gain in the power and speed of the ship.

The only points of advantage of the radial over the feathering paddle-wheel are its lightness, simplicity, and cheapness of construction. There are no working parts in it, and defects can be readily made good at little cost. Its propelling efficiency, however, is much less than that of the wheel with feathering floats, and the improvements in design and workmanship have made the latter so practically trustworthy, for the comparatively few services for which paddle-wheels are now required, that the radial paddle-wheel may be regarded as altogether a propeller of the past.

Feathering paddle-wheel.—In order to obviate the disadvantages resulting from the oblique action of the floats of radial paddle-wheels, especially in cases where the draught of the vessel varied considerably, feathering paddle-wheels have been introduced. The general form and arrangement of these propellers are shown in Figs. 284 and 285. The wheel consists of a wrought-iron framework, secured to a strong cast-iron centre or boss, keyed on the end of the paddle-shaft. The floats, instead of being fixed to the arms of the wheel, are carried on joint-pins, and their motion is controlled by the action of an eccentric, through rods and levers, in such a manner as to keep the floats approximately normal to the effective surface during their passage through the water, so that the whole of the thrust will be in a sternward direction. Its efficiency is at least 10 per cent. greater than that of the radial paddle-wheel when both work under suitable conditions, and the economy and efficiency resulting from its use far more than compensate for its increased first cost and expense of maintenance.

It is however more complicated, and requires more care and attention, than the radial wheel. It is very important that the working parts should be sufficiently strong to withstand the shocks to which

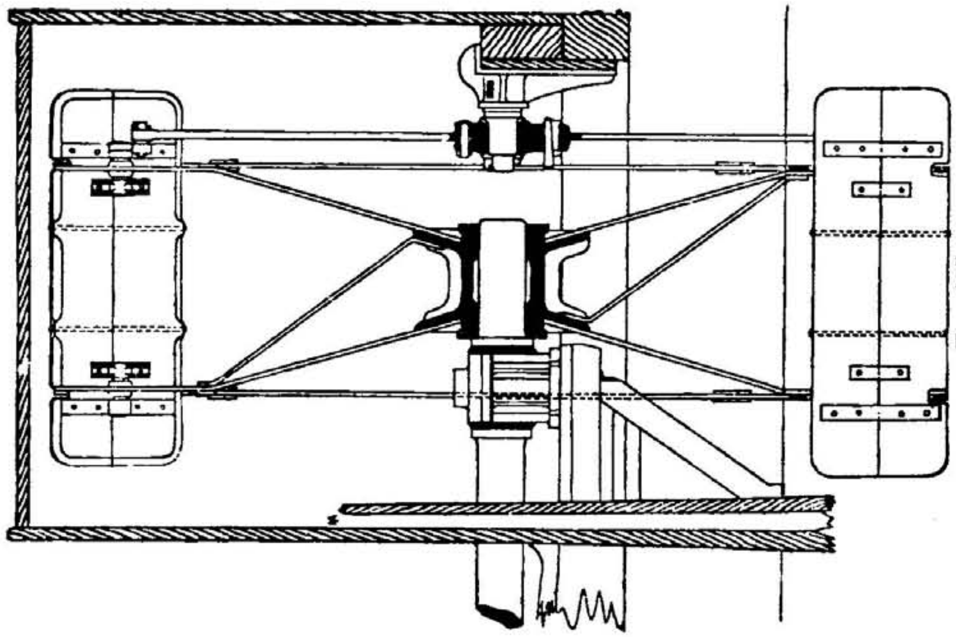

Fig. 285.

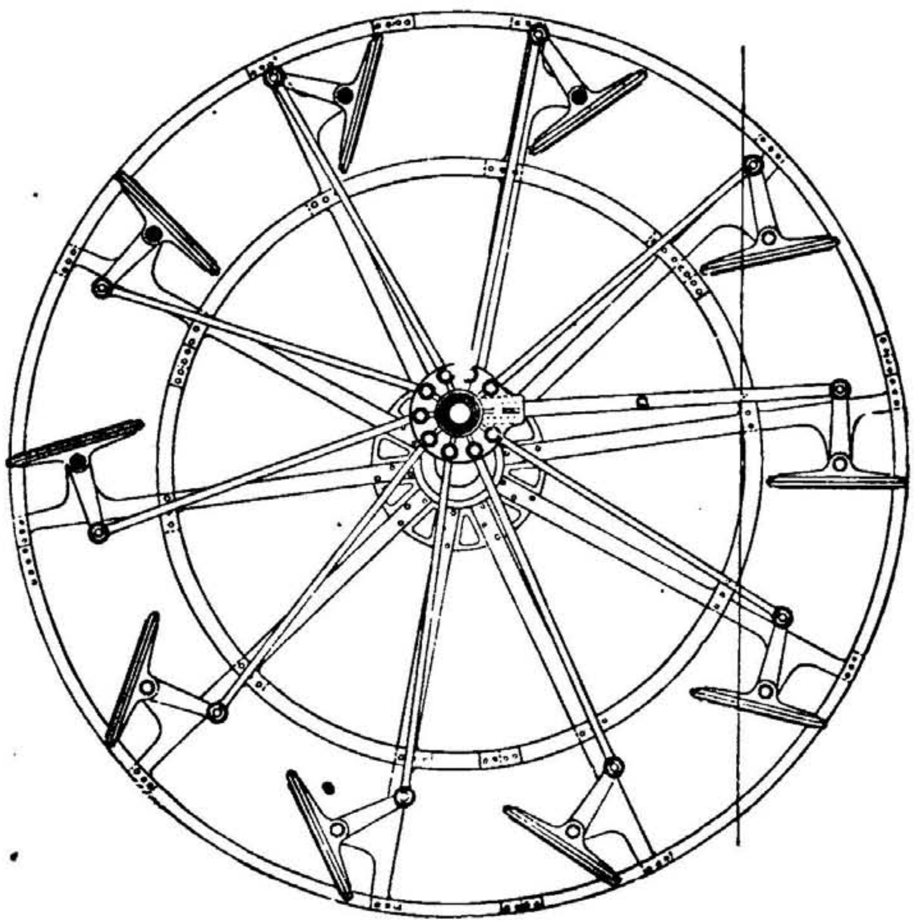

Fig. 284.

they are exposed, without undue straining, for damage to any part of the feathering apparatus is liable to paralyse the action of the entire wheel. These wheels are consequently made much heavier than the radial wheel, and are more difficult to properly support.

This complication and liability to serious injury might possibly have tended to prevent their being extensively used for long sea voyages, in preference to the simpler radial wheels, which, if damaged, could be so much more easily repaired. As, however, the paddle-wheel for ocean navigation has been entirely superseded by the screw-propeller, this point need not be further discussed, and there can be no doubt that for short voyages, river navigation, and towing purposes, for which alone paddle-wheels are now used, feathering floats possess very great advantages, enabling the wheels to be made of less diameter and width, and in consequence of their increased efficiency the indicated horse-power of the engines may be proportionately reduced for a given speed.

Dimensions and pitch of floats.—The floats in feathering paddle-wheels are generally placed about twice as far apart as the floats in the radial wheel; that is, the pitch of the floats is usually about six feet. They are also made deeper, say about twice the depth of the common float, for in this case the area of the race, or stream driven back on either side of the ship, is equal to the width multiplied by the depth of the float instead of the width of float multiplied by the depth of immersion, as is assumed to be the case with the radial paddle-wheel.

Eccentricity of feathering apparatus.—The method of determining the throw and position of the eccentric necessary to produce the proper action of the floats in the water may be easily explained by means of a skeleton diagram. In Fig. 286 let A represent the centre of the paddle-shaft, and K the centre of the eccentric pin or sheave that produces the necessary movement of the paddle-floats, the correct position of which is required to be found. For simplicity, the floats are supposed to be jointed at their centres. In practice this is not exactly the case, the joint being just behind the float, and as close to it as possible. In an actual design, this would render necessary a slight modification in the details of the following method of determining the eccentricity, but the deviation is small, and there will be no difficulty in making the required correction when the principles involved are understood. The circle B C D E F G, drawn with A as centre, through the centres, or joints, of the floats, may be taken to represent the paddle-wheel circle. Let W W represent the water-line, B and D being the points in which it is cut by the paddle-wheel circle.

Consider three floats in the positions shown by B, C, and D, one just entering the water, the second at its lowest point, and the third just leaving the water. In order that the motion of the floats through the water should be correct, moving as nearly as possible edgewise, relatively to the water in the paddle race, the directions of the faces of these floats produced, should meet at the point F, at the top of the paddle-wheel circle. If, therefore, from F, the highest point of the circle, straight lines, F B, F C, and F D are drawn, these will represent the directions of the faces of the paddle floats at these respective points.

From the centres of these three floats, B, C, and D, draw the float-levers, B*b*, C*c*, D*d*. These are usually at right angles to the float, and their lengths are about three-fifths of the depth of float. These values are arbitrary, and subject to convenience in any particular design; but the angle seldom deviates much from a right angle, and the proportionate length of lever given above is generally suitable. Having thus determined the points, *b*, *c*, and *d*, to which the radius rods from the eccentric have to be jointed, it is only necessary to find by plane geometry the centre, K, of the circle passing through them. K will then be the centre, and A K the throw, of the eccentric necessary to produce the required motion of the floats.

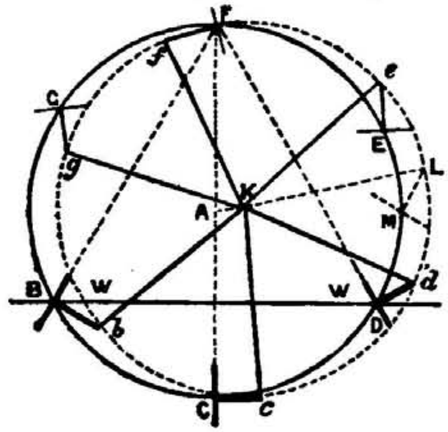

FIG. 286.

The velocity of the propeller race is clearly represented by the circumferential velocity of the circle B D F G, and the effect of the motion produced by the action of the eccentric, thus determined, will be to cause the floats, while *in the water*, to move as nearly as possible edgewise, relatively to the propeller race, and thus prevent loss from oblique motion. By drawing floats in other positions, it will be seen that their action when *out of the water* is far from being free from vertical reactions, but these, operating only on the air, may be neglected.

Paddle-shaft bearings.—The shaft carrying the paddle-wheel is called the paddle-shaft, and is sometimes supported by two bearings, one on the ship's side, and the other on a beam, called the *sponson* or *spring beam*, on the outside of the paddle-box. In this case, the feathering apparatus has to be worked by a large eccentric on the paddle-shaft, to which the radius rods are attached.

Overhung wheels.—The most general arrangement, however, is that shown in Figs. 284 and 285, in which the paddle-wheel is overhung and supported by a single bearing on the ship's side, the outer bearing being dispensed with. In this case the feathering motion is produced by attaching the radius rods to a sheave working on a pin carried by a bracket fixed to the outer side of the paddle-box, in the proper position, eccentric to the wheel, to produce the required movements of the floats.

Driving and radius rods.—In the feathering apparatus, one of the guide or radius rods, called the driving rod, is rigidly fixed to the eccentric, to make it rotate about the axis K. The remainder of the rods are simply jointed to the eccentric, as well as to the float-levers, with pins. In Fig. 284 the driving rod is marked D. All the joints in the feathering apparatus should be bushed either with gunmetal, white metal, or lignum-vitæ.

Details of paddle bearings.—The outer bearings of paddle-wheels, when they are so fitted, cannot be examined when the engines are at work. Guide-boards or troughs are therefore fitted on the side of the paddle-box, so that the water carried up by the wheel is caused to constantly run on these bearings to prevent their overheating. This splashing and churning action of the wheel on the water is also often

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1856.

STEAMSHIPS BETWEEN THE UNITED STATES AND EUROPE.

We give below a table of the several ocean steam lines between the United States and Europe:—

	Names.	Class.	Tonnage.
	LIVERPOOL AND NEW YORK.		
Collins line	Atlantic	Paddle-wheel	3,000
	Baltic	Paddle-wheel	3,000
	Adriatic	Paddle-wheel	4,200
	Ericsson	Paddle-wheel	1,800
Cunard line	Persia	Paddle-wheel	3,600
	Africa	Paddle-wheel	2,250
	Asia	Paddle-wheel	2,260
	Europa	Paddle-wheel	2,250
	LIVERPOOL AND BOSTON.		
Cunard line	America	Paddle-wheel	1,800
	Arabia	Paddle-wheel	2,250
	Canada	Paddle-wheel	1,800
	Niagara	Paddle-wheel	2,250
	GLASGOW AND NEW YORK.		
Scotch line	Edinburgh	Screw	2,500
	New York	Screw	2,150
	Glasgow	Screw	1,962
	LONDON, CORK, AND NEW YORK.		
Cork line	Minna	Screw	1,300
	Brenda	Screw	1,300
	NEW YORK AND HAVRE.		
Cunard line	Ætna	Screw	3,000
	Jura	Screw	3,000
	Emeu	Screw	2,000
	Lebanon	Screw	2,000
	Cambria	Paddle-wheel	1,800
French line	Alma	Screw	1,500
	Barcelona	Screw	1,500
	Sebastopol	Screw	1,500
Old Havre line	Arago	Paddle-wheel	2,700
	Fulton	Paddle-wheel	2,500
	Union	Paddle-wheel	2,000
	ANTWERP, SOUTHAMPTON, AND NEW YORK.		
Belgian line	Belgique	Screw	2,590
	Constitution	Screw	2,500
	Leopold I.	Screw	2,500
	Duc de Brabant	Screw	2,500
	Congress	Screw	2,500
	NEW YORK, SOUTHAMPTON, AND BREMEN.		
Bremen line	Washington	Paddle-wheel	2,000
	Hermann	Paddle-wheel	2,000
	LIVERPOOL AND PHILADELPHIA.		
Philadelphia line	City of Baltimore	Screw	2,367
	City of Washington	Screw	2,380
	City of Manchester	Screw	2,109

In addition to the above, a line has been established between Portland and Liverpool, in which the Sarah Sands and Canadian run.