The World's Columbian Water Commerce Congress

Chicago, 1893

THE WORKING

OF THE

FIRST SHIP-RAILWAY

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BOSTON
DAMRELL & UPHAM
The Old Corner Bookstore
283 Washington Street

THE WORKING OF THE FIRST SHIP-RAILWAY.

The first ship-railway was laid by the present writer at Edinburgh Exhibition, in the year 1890, as a practical illustration of his system. He had then developed the flexible car, curved and graded ship-railway, for the transport over land, by multiple line railways on ordinary grades and curves, of ocean-going vessels fully laden with cargo. Starting from the point of view of the ordinary railroad capable of traversing an undulating country, the author had labored for years to provide on a ship-railway car of great length, width, and height, the means of insuring lateral flexibility of the wheel base and vertical flexibility of the car, while leaving the rigid length of the ship unstrained.

The leading principles upon which ship-railway cars must be based are: (1) the distribution of the weight of the ship and the car over a great number of wheels on parallel lines of rails, so that the maximum pressure on each wheel should not exceed the resistance of the permanent way or the strength of the wheel and axle; (2) the retention of the distribution of the pressure over the skin of the ship upon the ship-railway car the same as at sea; (3) the adaptation of the car for running over the usual changes of railroad gradients by making it flexible vertically; and (4) the adaptation of the ship-railway car for running round curves, and through shunts, points, and crossings, by making the wheel base flexible laterally.

The first of these principles obtained necessarily in any attempt, however crude, at the development of a ship-railway car. For a line that was perfectly straight and horizontal this principle might be sufficient, with extraordinary care of the vessel and smoothness of the ship-railway.

But for practical and certain working the other three principles, as developed by the author, are really essential. The second is embodied in the contrivance of hydraulic cushions, the third in making the cars in sectional lengths connected by hinges, and the fourth in the contrivance called the compound bogie.

While exhibiting, in illustration of his lectures before the Chambers of Commerce and other bodies in Britain, a set of working models of a ship-railway with curves and grades, over which a model vessel and car were run, the small scale on which these were necessarily constructed induced the author to promise a demonstration upon a working scale by laying down a ship-railway in the grounds of Edinburgh Exhibition.

The site was obtained, and the line set out in February, 1890, three months before the opening of the exhibition. This site was a triangular field on the south front of the exhibition, separated from the rest of the exhibition grounds by the Union Canal (Fig. 1). The canal frontage afforded an opportunity for the launching and redocking of the vessels run over the ship-railway, while the canal banks and the undulations and shape of the field necessitated steep grades with frequent changes of gradient and sharp curves in opposite directions (Fig. 2).

The Edinburgh Exhibition Ship-railway consisted of two parallel lines of ordinary railroad, each 20 inches gauge, with $3\frac{1}{2}$ foot space between, giving an aggregate ship-railway gauge of 7 feet. The rails were flat-bottomed bulb rails, 16 pounds per yard, laid on sleepers of timber, and fish-plated. The undulations of the ground and the canal banks were graded by means of timber trestles and one cutting averaging 4 feet deep near the middle of the line.

A passing place for the cars was formed at the middle of the line, 150 feet long between the points, which showed the working of points and crossings on the flexible car (or curved and graded) ship-railway system. Platforms were erected at this point, from which passengers embarked and debarked while the boats lay on the hydraulic cushions in the cars alongside (Fig. 3).

Two flexible ship-cars were run simultaneously in opposite directions on the ship-railway, drawn by a stationery steam-engine and wire rope, the engine being placed at the south-west corner of the ground, near the canal bank. Two boats and two gondolas were procured, each 38 feet long, and 7 feet 6 inches beam, drawing 2 feet of water when laden with 40 passengers. Two of the boats were passed in opposite directions along the canal, while at the same time other two were being carried along the ship-railway on the cars. Two boats were sufficient to accommodate passengers during the latter part of the exhibition season, owing to the defective arrangements of the exhibition, and the unfavorable weather.

During the whole of the time from its commencement in the beginning of July to the close of the Exhibition, the ship-railway worked most successfully.

The ship-railway with engines, cars, and boats cost $20,-000; and the working expenses and ground rent amounted to upwards of $5,000.

The passengers embarked from the station platform while the vessel was lying afloat on the car. The additional weight of the passengers only caused the boat to settle down to the new flotation level on the hydraulic cushions, the water within the cushions rising a few inches in the vertical portion of each cushion between the fixed upright side of the car and the boat. The boat did not move or lurch in any way upon the cushions, being gripped firmly in position by the frictional adhesion of the cushions to each other and to the surfaces of the boat and the car. The boats were always perfectly water-borne by the hydraulic cushions while seated on the cars. The illustration, figure 4, shows a midship section of the boat laden, one of the hydraulic cushions, and flexible car, and an end elevation of a pair of compound bogies as seen from the mid-section of the car (Fig. 4).

The hydraulic cushions were soft flexible tubes made of thin waterproof cloth of uniform diameter from end to end, one end being sealed up, while the other end was left open. They were laid in a continuous row athwart the car, the closed end of the cushion rising only to the bilge of the boat, while the open end was carried up the fixed side of the car to allow the water to rise to give whatever head of pressure was required to float the boat under any circumstances. The bottom of the car formed a platform in four segments, with one rigidly attached side rising to the height of the boat. The other side of each segment rose no higher than the bilge of the boat; and the two middle segments had movable sides attached to the car at the bilge level, by hinges, on which they folded down to let the ship float on or off sidewise or endwise, and raised to retain the vessel in position. The closed ends of the cushions lining the folding sides were attached to the sides, so as to rise or fall with them while retaining the water within them. The illustration (Fig. 5) is a plan of the hydraulic cushions as they appear on one-half of the car with the folding side up, and on the other half with the folding side lowered for shipping or launching the vessel.

The cars were each made in four sections, joined together by hinges at the bottom, to make the car body flexible vertically, in order to accommodate the car to the changes of gradient, without straining the vessel lengthwise or lifting any of the bogies off the line. The interposition of the hydraulic cushions makes this flexibility perfect while the vessel is on the car. Fig. 6 shows the body of the car in four segments, hinged together at the points marked A.

The movement of the cars round the curves, which were only 95 feet radius, and through the points and crossings was provided for by making the wheel base flexible laterally by means of an invention of the author's called compound bogies. These consisted of two separate trains of four trucks each, on each line of ordinary railroad; that is, each car was supported on four trains, numbering altogether sixteen small trucks. The distinctive feature of these compound bogies is that, while each train of trucks is linked together end to end, so as to allow free lateral movement, guided only by the wheel flanges on the rails, the train has only a single centre-pin connecting it, through the second truck from the outer end, to the bottom or platform of the car. The car thus covered four independent railway trains, linking them together by the four centre-pins, while leaving them free to bend laterally round the railway curves on which they were guided by the wheel flanges. While the car body rested and swivelled on the centre-pin trucks in the usual way, on the other three trucks of each train rubbing plates slid sidewise on a slender iron rail as the car passed round a curve. Fig. 7 is a plan of the four trains of trucks in position on a curve to support the car body, the platform of the car being shown in outline.

The two folding sides of the middle segments of the cars were raised and lowered by means of a lever on the fixed side, the motion being communicated by cranks and rods carried across underneath the platform. One man standing on a shelf on the top of one segment of the fixed side of the car was able easily to work the folding sides simultaneously by a single motion of the lever. Fig. 8 is made from a photograph of a car containing a boat, and shows the fixed side and the front of the car with the shelf and lever for working the folding sides.

The boats were sailed regularly, one each way along the Union Canal, shipped on the cars in a minute and a half, hauled along the railway in seven minutes, including three and a half minutes for debarking and embarking passengers at the station, and were launched on the canal again without even stopping their way. The boat, when shipped on the car, was simply enclosed while still afloat within the folding and fixed sides of the car, and settled automatically on to the cushions while the car was being drawn up the incline out of the canal, where it remained firmly seated without any adjustment or vibration during the whole of its journey over land.

The ship-railway was inspected by a special jury consisting of Sir Edward Reed, K.C.B., etc., and Mr. W. R. Kinipple, M. Inst. C. E., who subsequently reported *inter alia:* —

"The boats in use at the exhibition are 38 feet long by 7 feet 6 inches beam. The operation of placing one on the car on the incline in the canal takes about one and a half minutes, and the car with the boat is then by rope traction hauled up the incline and over the railway system till it reaches the incline in the canal at the other end of the line, where the boat is set free and afloat in the water in less than a minute.

"The boat takes its bearing on the bags of water without the slightest trouble, and remains firmly seated throughout its journey over land. At the curved portion of the line the bogies adjust themselves thereto, sliding laterally underneath the car which is rigid horizontally. The car which is hinged vertically adapts itself to all the changes of gradient, and where such occur the water in the cushions under the keel and floor of the vessel gets displaced to an extent corresponding with the changes of gradient, the vessel remaining, however, always water-borne, owing to the diameter of the cushions being arranged to suit the maximum change of gradient. In the line at the exhibition these cushions are 8 inches in diameter. For dealing with large vessels and with gradients likely to be adopted in practice, 3 feet in diameter may be taken as a maximum size.

"With regard to the bags it might at first sight be thought that these would wear out so rapidly as to be unreliable or be a source of expense; but after seeing those at Edinburgh, upon which boats have been shipped and unshipped several thousand times, and which, although of very flimsy material, are still in good condition, any doubt in this respect may be at once dismissed.

"In practice, the water-bags would be made of stout, seamless canvas, capable of sustaining safely, say, 100 pounds' pressure per square inch, and the surface in contact with the skin of the vessel would be protected by a covering of ordinary canvas or rope-matting.

"Sir E. J. Reed and myself examined the system carefully, had the boat shipped on to the car, transported over the railway, and unshipped at the other end. We paid especial attention to the action which took place at changes of curvature and gradient; and we are both of opinion that the system is a thoroughly practical one, and that by means of it vessels of large tonnage can be safely transported overland."

Mechanical and Hydraulic Principles.

The first principle observed in the design of a ship-railway car is the distribution of the weight of the laden vessel and the car over a sufficient number of wheels to keep the weight per wheel well within the limit of the strength of the wheel and axle. This condition is met by increasing the number of railway lines, and also the number of wheels and axles on each line. This provision is essential to any system of ship-railway, and is the only new departure in mechanical principle required upon the Chignecto Ship-railway, where the lines are practically level and straight throughout their whole length.

In order to adapt his cars to railway curves and gradients, and especially to changes of gradient, the author treated the horizontal and vertical flexibility of the ship-railway car separately. His first departure was made with the invention of the compound bogie (English patent No. 13298, 1886), in adapting which to long grain cars for loads of 150 tons on a single line of railway the idea of hydraulic or pneumatic cushions was first introduced (English patent No. 11207, 1887) to meet changes of gradient on long cars.

The difficulty and costliness of making closed cushions to withstand the enormous pressure to which they might be subject, led the author to work out the problem of open hydraulic cushions made of a flexible waterproof material, consisting of plain tubes of waterproofed canvas, with one or both ends open, laid in a continuous row athwart between the ship and car. The horizontal portions of the tubes contain a little water, part of which is forced up the vertical portions of the tubes till it reaches the flotation level of the vessel. The vertical portions of the tubes form reservoirs in which the water, rising and falling automatically as the vessel passes over a change of gradient, adjusts its volume to the varying spaces between the vessel's bottom and the car, and at the same time compensates for any change of pressure by a corresponding increase or diminution of head.

While the complete set of hydraulic cushions between a vessel and car represent a tank of water, inasmuch as the vessel is completely water-borne, the tank represented by the cushions is cut up into independent parallel strips athwart the ship, which makes the water incapable of flowing lengthwise of the car or ship. The cushion tank may thus sit upon a steep gradient while the vessel is equally water-borne from end to end, on the same thin film of water as on the level.

Of course, as it is only the vertical pressures that support the ship vertically, the cushions might be stopped at the level of the bilges and the head of pressure equivalent to the weight of the vessel obtained by carrying up small pipes to a cistern. The incompressibility of water was found by the author to make such cushions unworkable on a large scale. On a series of practical trials of such cushions and small upright pipes made at Aberdeen and at Loughborough in the year 1891, the closed cushions became virtually hard incompressible pads, when subjected on a car in motion on the rails to sudden jolts or changes of gradient. On hydraulic cushions of uniform section, however, the car runs at a high speed over a rough railroad and changes of grade with perfect smoothness. Vessels are even less exposed to strains of any kind while borne along on the hydraulic cushions on a ship-railway car than on a calm day at sea.

Besides providing for the ascent or descent of grades and for the prevention of shocks and the distribution of pressure over the skin of the ship, the hydraulic cushions render it unnecessary to make the car body rigid or water-tight. The car body may therefore be made up of as many separate lengths connected together by hinges working vertically as are required for bending over changes of gradient.

While the vertical portions of the hydraulic cushions serve to prevent the vessel's sides from bulging outwards, they are also carried up the full diameter to contain a supply of water to compensate for the varying thickness of cushion beneath the vessel on these vertical curves. Any departure from this simple plan would be unworkable. The plane parallel tube subserves all purposes perfectly.

The adaptation of the ship-railway cars to varying sizes and shapes of ships is accomplished partly by the hydraulic cushions and partly by sliding one or both sides of the car towards or from the heel line. The cars, being made up of separate segments, each connected by a pair of hinges, may be disconnected, and made up in longer or shorter lengths. It may be convenient in practice, however, to provide a variety of cars to suit various sizes and kinds of ships, just as various kinds of wagons are adapted to their respective descriptions of traffic on an ordinary railroad.

Perfect steadiness of fixture is obtained on the vessel by the frictional adhesion of the cushions together and to the car and the vessel. This is an important new principle, brought into use by the cushions as compared with an open tank, and indicates the advisability of adhering to a series of comparatively small cushions instead of two or three large ones.

An additional principle introduced in the hydraulic cushions, preventing swaying or lateral oscillation of the vessel on the car, is the friction of the water within the cushions. The water flows up and down within the cushions, having to expand or open up the vertical portion of the cushion in rising. The cushion acts as a brake, preventing the water from jerking or splashing upwards or flying out of the cushion by sudden jolts of the car over inequalities of the line or changes of gradient. The fluid friction and the enclosure of the water by the soft folds of the cushion make all movements, however free and sudden, perfectly smooth and safe.

When the hydraulic cushions are not supporting a vessel, only their horizontal portions are filled with water ; and the pressure outwards on the cloth does not exceed two or three feet of head, or about one pound on the square inch. On the ship settling on to the cushions, it compresses the horizontal portion of the cushions, forcing the water up the vertical portions until it attains to the flotation level of the ship. The internal pressure of the water on the cushions is then counterbalanced by the weight of the ship and the resistance of the car and contiguous cushions. If we consider a single cushion without these outside counterbalancing pressures, the maximum pressure that can be brought upon it is that due to the immersed depth of the ship,— only 8 or 9 pounds per square inch by the largest vessels. But, taking the car as a whole, the unbalanced pressures on the cushions do not exceed two or three pounds per square inch, so that there is no danger of the hydraulic cushions bursting. If the cushions were closed and small pipes carried up to reservoirs, the slowness of the flow of the water from the closed cushions would introduce this danger, which has thus been specially guarded against by the author.

There is no danger of the cushions being cut or abraded by the vessel nor by barnacles or any hard, sharp substance getting in about them accidentally. It is essential to cutting any substance that there should be sufficient resistance to the cutting instrument. The water within the cushions presents little or no resistance to cutting, so that the hydraulic cushions are practically invulnerable.

The body of the car does not bend sidewise, its only flexibility is vertical. It rests, however, upon the compound bogies, two trains of trucks on each railway line with only one centre pin to each train. The whole lateral movement in going round curves or through points and crossings is on the compound bogies under the car, and the rails form the guide for the bogies.

The same principle applies to brake power to govern the momentum of the ship-railway car as to the distribution of the weight over a great number of wheels. The momentum being a function of the weight, a continuous brake applied to every wheel will possess exactly the same control over the momentum of the ship-railway car as it would over a railroad train in proportion to the weight per wheel.

The working of the Edinburgh Ship-railway also demonstrated the superior ease and celerity with which the vessel may be docked and launched on a flexible ship-railway car lined with hydraulic cushions, and raised and lowered from the water by means of an inclined ship-railway or slipway rather than blocked up on a rigid car, and raised and lowered by a vertical lift. On the author's system the ship-railway simply terminates at a level under water deep enough to float the vessel on or off the car.

The ship-railway station with its raised platforms was a miniature production of the future ship-railway station at inland towns *en route*, consisting of huge, many-storied warehouses for platforms, as indicated by the cross section, Fig. 9.

By means of curved and graded ship-railways the capabilities of the system of maritime transport over land are vastly extended. The crossing of isthmuses is the least important function to be subserved by this system. Being independent of locks, lifts, or turn-tables for changes of direction or level, and capable of following any ordinary undulations of country, a main trunk ship-railway line may connect all the leading manufacturing and mining or agricultural centres in a country with the ocean; while branch lines of less aggregate gauge for smaller vessels may connect the lesser towns. The aggregate gauge may be economically widened by laying additional lines to suit larger vessels and accommodate increasing traffic, while all the time the ordinary goods and passenger cars may be running over the single lines composing in the aggregate the ship-railway. Ship-railways as a system of inland maritime transport are impracticable upon any other basis than that of the introduction of ordinary curves and grades with flexible cars.

The Chignecto Ship-railway owes its inception to local needs and conditions. While a railway line straight and level was practicable right across the isthmus, the conditions of the tides and the nature of the soil were such as to make the formation of a ship-canal impracticable. The particular schemes of Tehuantepec or Toronto were promoted to accommodate the needs of their respective positions; but no system of ship-railways, like a railroad or canal system, had before this been advocated for general purposes of inland maritime traffic to supersede and extend the functions of canals. A lift at every change of level, a turn-table at each change of direction, a huge traversing table at every passing place for cars, and the frequent detention of vessels for these operations would be a clumsy makeshift for the swift, continuous journey by flexible car, over a curved and graded ship-railway. It is impossible to make a system upon the rigid car principle. It would be far too costly and slow in construction and working.

Comparing the curved and graded ship-railway with a ship-canal of equal vessel capacity,—the ship-railway claims, owing to greater speed, five times the traffic capacity,—it would cost but one-fourth of the price per mile for construction, the actual cost will vary little from the estimated cost, the working expenses will be less per ton, and the rates upon goods for transit would be little more than the ocean freights. The mechanical advantages of the system were thoroughly demonstrated by the Edinburgh Exhibition Ship-railway, and the commercial advantages were so evident that only the occurrence of the Baring crisis at the close of the Exhibition year postponed its application to the inland navigation of Britain.

In conclusion, the author may quote the following from Mr. Kinipple's report:—

"The advantages of this system of transport are so obvious that it seems almost unnecessary for me to refer to them. Wherever an ordinary railway is feasible, a ship-railway can also be constructed, and vessels conveyed overland from sea to sea, or inland to any destined point. It has all the merits of a ship-canal, with the great advantages of the cost per mile being a mere fraction of that of a canal, whilst its traffic capacity would be greater as the speed of transport would be higher.

"As is well known, there are many places where ship-canals would be most serviceable; yet the elevation and other features of the country to be traversed are such that, although presenting no difficulty in regard to railway construction, they are prohibitive for canals on account of the great cost of locks or lifts, viaducts, embankments, etc., which would be required. For such places the ship-railway is eminently suited, as there would practically be no extra expense in construction on account of difference of level along the route to be traversed.

"A further important advantage which the ship-railway possesses is the simple manner in which it may be enlarged, when desired, for the conveyance of vessels of increased tonnage. Suppose that a ship-railway were constructed to carry vessels of, say, 1,000 tons burthen. A railway for this purpose would consist of three parallel tracks of permanent way of 4 feet 8½ inch gauge; and, should it be desired at a future time to provide for vessels of larger tonnage, all that would be required would be to widen the line, and lay down one, two, or more extra tracks to suit the vessel to be dealt with, and provide some cars of increased size.

"No existing works would be disturbed, nor would there be any interference with the ordinary traffic along the line during the progress of the widening; and as the bridges spanning roads, streams, etc., would all be under bridges, there would be no necessity to pull down or disturb any of these, but merely to widen them.

"With canals the case is altogether different. To increase their capacity by deepening or widening, nearly all structural works, such as quay walls, locks, lifts, bridges, etc., would be interfered with, and would require to be rebuilt.

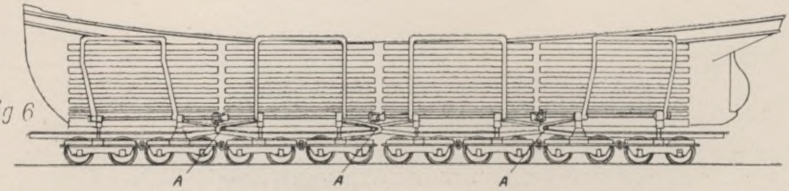
"The ship-railway system is, in reality, most elastic in regard to its adaptability to suit the requirements of an expanding trade. Thus there may be a main line of railway across a country consisting of a series of tracks along which the vessels of all sizes of tonnage may be travelling on suitable cars, and utilizing two, three, four, five, six, or more tracks, according to the tonnage of the vessels; whilst branches from the main line need only to be constructed of dimensions to suit the vessels utilizing such branches, and increased, when required, to accommodate vessels of larger tonnage.

"It must further be kept in view that the ship-railway, being merely a series of tracks laid to the ordinary 4 feet 8½-inch gauge, with ordinary locomotives used for the purpose of traction, there is nothing to prevent ordinary railway traffic, especially goods and minerals, being carried on in addition to the ship traffic, and connections established with the railway system of the country.

"I need hardly point out that at any town or locality along the route of a ship railway a basin or dock may be constructed in which vessels may lie afloat and receive or discharge cargo and adjoining which ship-building may be carried on, so that this latter industry, instead of being confined as at present to certain suitable localities on our coasts and rivers, may be carried on in the districts where the iron is produced, and save the cost of carriage or freight of material."

FIRST SHIP RAILWAY.

Fig 6



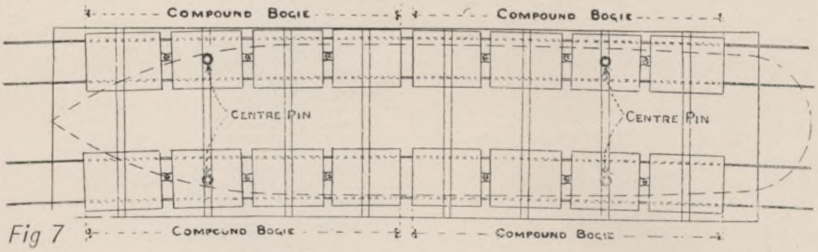
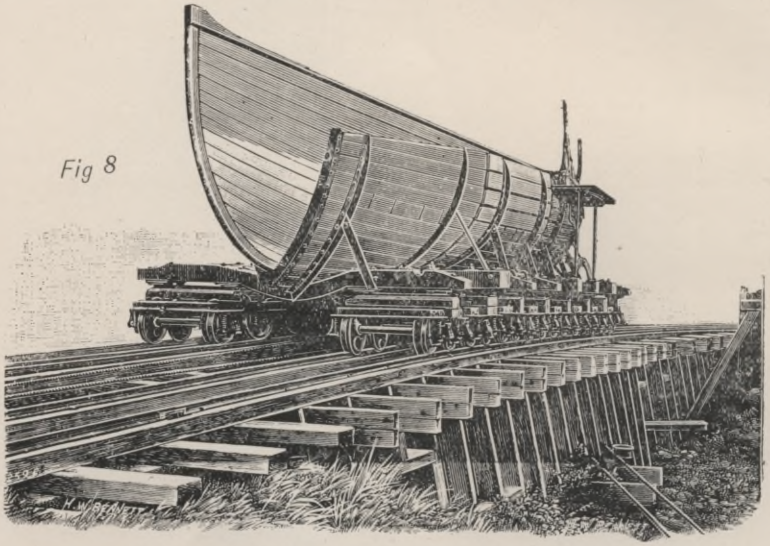


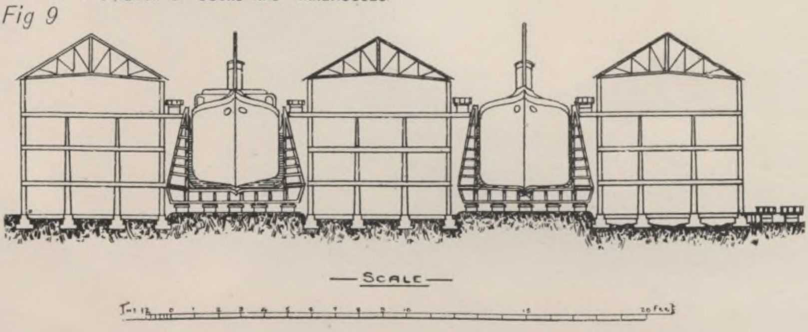
Fig 7

Fig 8



FLEXIBLE CAR SHIP-RAILWAY
DIAGRAM OF DOCKS AND WAREHOUSES

Fig 9



FIRST SHIP RAILWAY.

Fig 1.

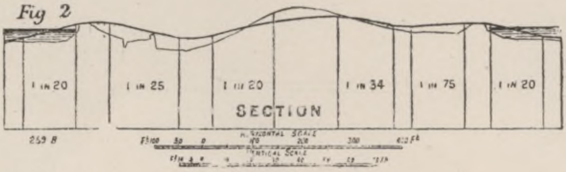


Fig 2

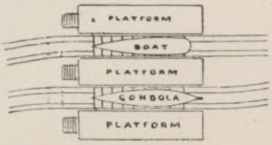


Fig 3 B

Fig 3 A

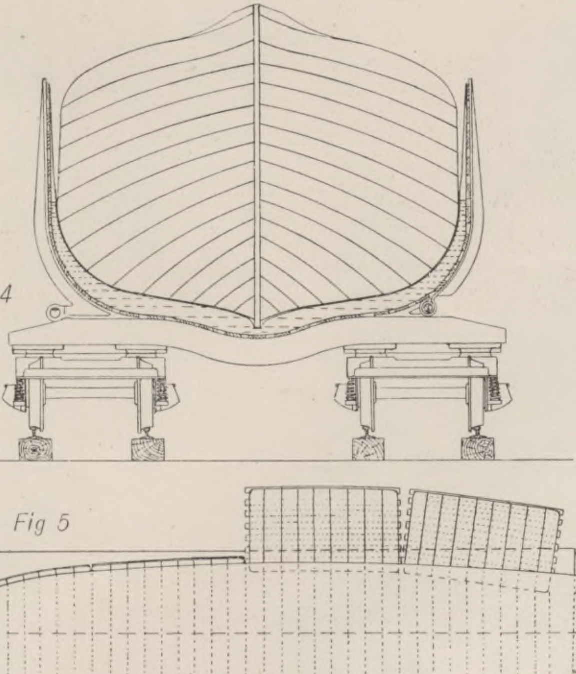


Fig 4

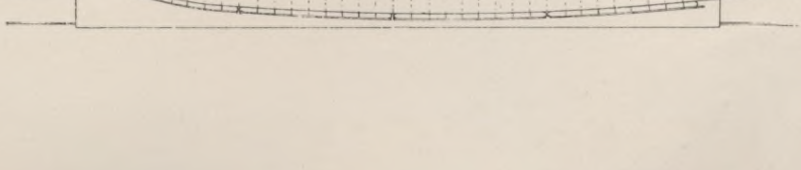


Fig 5