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# BRUNEL'S "GREAT EASTERN" STEAMSHIP THE LAUNCH FIASCO - AN INVESTIGATION

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## Introduction

Gloucester's position on the lower reaches of the River Severn assured its function as a centre of trade from the earliest times. Being the lowest crossing downstream the city was also of military importance during the Roman Occupation. Although river trade developed gradually over the centuries it was the completion of the Gloucester-Sharpness Canal in 1827 with the consequent increase in trade, further boosted by the arrival of the railways in the 1840's which gave Gloucester a "state-of-the-art" transport infrastructure. New industries evolved as a result, a process which continued into the 20$^{th}$ Century. During this period familiar Company names would emerge, establishing Gloucester as an important manufacturing centre in both peace and war.

It was the Bristol and Gloucester Railway which first linked the city with I.K. Brunel. Laid to his "Broad Gauge" it was Brunel s first offensive northwards from Bristol in his campaign to penetrate the Midlands, already dominated by the "Narrow" or standard gauge as we know it today. The station complex at Gloucester was the interchange for the two gauges and became notorious as the site of the first skirmish in the so-called "Gauge War" with a staged demonstration of the freight and luggage transhipment difficulties inherent with the break of gauge.

Although the City's connection with Brunel is commonly associated with his railway works, indeed thanks to the short-lived Gloucester and Dean Forest Railway and the South Wales Railway, Gloucester could boast the largest concentration of his unique "Balloon" flange wrought iron bridges in the kingdom, there is perhaps a less well known connection with the last and most controversial of all his works his Great Ship-The "Great Eastern". A connection which prompted this writer, born and raised in that city, to look more closely at Brunel's design rationale for the launch of his third and final ship.

## Origin of the project

Expansion of British trade, particularly in the East, necessarily placed increasing demands on sea transport with the need for increased carrying capacity and range. Fuel consumption was the limiting factor for long ocean voyages under steam power so increasingly larger ships were needed to obtain the necessary coal capacity. In 1851 Brunel had advised the Royal Australian Mail Company that ships of 6000 tons displacement would be the minimum size capable of making a regular mail run to Australia, but a refuelling stop would be required at the Cape of Good Hope. The Company duly noted his advice and purchased two slightly smaller ships to his specification, the Victoria and the Adelaide. They were both built by John Scott Russell; it was this contract which enjoined the two men, leaders in their respective disciplines, to develop Brunel's ideas for a steamship which could voyage to Australia without refuelling. The outcome was a proposal for a ship of a nominal 27000 tons displacement, nearly 700 feet long, constructed of riveted wrought iron and powered by both screw and paddles. This was to be a vessel which would fascinate the public during construction. A vessel whose technical and financial demands would result in the destruction of the professional relationship between Brunel and Scott Russell, leading to the latter's bankruptcy.

**Construction**

By early 1852, having established the design Brunel, and Scott Russell were faced with the problem of funding the project. As luck would have it, a potential investor was ready to hand - The Eastern Steam Navigation Company. This company had been formed in 1851 to compete for the Australian Mail Contract, its bid had been unsuccessful thus it was left without an objective. Following an approach by the ever persuasive Brunel the Directors were soon convinced of the viability of the proposed steamship and he was appointed Chief Engineer in overall charge of construction. It is at this point that the Gloucester connection begins, for amongst the Directors are named two Gloucester businessmen - Samuel Baker, a Gloucester merchant turned banker and Richard Potter, a Gloucester timber merchant turned railway magnate. (1).

The E.S.N. invited tenders for the contract to build and launch the hull, but the magnitude of the task must have been considered too risky to attract many competitive bids from iron shipbuilders, although there were several submissions against the separate contracts for the paddle and screw engines which were required to generate the 7000 horse power estimated to be necessary to drive the ship at 14 knots, her design speed. It was no surprise that Scott Russell was awarded the contract for construction and launch together with the contract for the paddle engines, after all he had ably assisted Brunel in the development of the scheme. As a shipbuilder he had a design and iron fabrication capability second to none, he was also one of the leading exponents of the emerging science of Naval Architecture. His shipyard was on the North bank of the Thames, East of the City of London, located in flat marshland known as the Isle of Dogs, in those days yet to be developed. At this point the width of the river was hardly greater than the length of the proposed vessel so a conventional stern first launch was out of the question, both men agreed on the only viable alternative - a sideways launch. However, they were at odds as to whether the hull should be allowed to slide freely into the river or be controlled. In the event, as we shall see, brute force was needed. Work began on December 22$^{nd}$ 1853. Before construction could begin it was necessary to strengthen the mud bank of the Thames to support the weight of the hull and its machinery, some 12000 tons in all. To achieve this piles were driven into the mud over an area encompassing the length and breadth of the ship, leaving four feet standing proud. On top of the piles a wooden platform was assembled upon which were laid the flat iron plates forming the underside of the hull - there was no keel as such. The vertical bulk heads were assembled in-situ and the hull plating riveted on from the bottom up. No cranes were used, all the iron plates were man handled into position and hot riveted. Assembly of this enormous structure required careful planning, tooling and considerable skills from Scott Russell s workforce, a fact which is seldom noted by writers of Great Eastern histories, past or present. Indeed, the magnitude of the achievement is astonishing.

As the form of the ship began to dominate the vista across the bleak expanse of the Isle of Dogs, public curiosity was aroused; the site became a tourist attraction and a focus for press reporting and speculation. However all was not well at top management level, the project was short of money and Brunel had accused Scott Russell of misappropriation of materiel. The upshot of it all was bankruptcy for Scott Russell in February 1856 with the E.S.N. taking direct control of the project leaving Brunel in charge of construction, but not in control of spend, this was the responsibility of John Yates the E.S.N. Company Secretary. Yates was well aware that work could not progress without the cooperation of Scott Russell and his team, so it was arranged that he would continue as a sub-contractor responsible to Brunel for execution of agreed quantities of work. In practice, this proved divisive putting the two men at loggerheads and an exasperated Yates eventually took Brunel to task over the matter in no uncertain terms (2). Despite all the difficulties construction progressed, to the extent that by early 1857 Brunel began preparing the site for the launch ways. However by this time, Scott Russell had been discharged from his contract and would not be directly involved in the forthcoming struggle to get the ship into the water.

A transcribed copy of the launch specification survives (3) in which Brunel sets out his requirements for the launch ways. The hull would be supported on two wooden cradles 120 feet wide, these running on a piled foundation overlaid with 12inch square timbers extending 240 feet to the low water mark. From the wording in the specification it is evident that his original intention was to follow conventional practice and launch on greased wooden slide ways. However at some point a change of mind occurred and he decided to use iron at the sliding interface. The rationale behind this approach is difficult to understand. The explanation offered in the 1870 account of his works (4) contends that he was concerned that high loads at the sliding interface would cause all grease to be squeezed out and thus give rise to wood to wood binding and subsequent jamming of the cradles. This irrational fear was contrary to the practice of the day and indeed to all subsequent practice - provided the bearing pressure between the slides is kept low enough, greased wooden slide ways will always work, it is a matter of adequate dimensions to match the size of the vessel. Brunel's decision to use iron as the sliding medium was, in this writer's opinion, the greatest technical misjudgement of his career, as we shall see.

The groundwork for the launch ways required large quantities of timber and concrete, executed under a separate contract, it is at this point that the next Gloucester connection emerges. Messrs Tredwell were railway contractors whose main yard and workshops were situated on the east bank of the Gloucester and Sharpness canal, just south of the docks. They had completed several contracts under Brunel's direction, including one on the Gloucester and Dean Forest Railway and must therefore have earned his trust and confidence - no easy matter! Although not local men, the partnership comprised four brothers Thomas, William, John and Solomon and they no doubt provided valuable local employment. Tredwells were awarded the contract in early 1857 and with a planned launch date in August 1857 the timescales were very tight. To begin with 960, 12 inch square piles had to be driven into the soft Thames foreshore to form a firm foundation for the two concrete and timber launch ways. This task was accomplished with the aid of two pile drivers supplied by another Gloucester-based contractor William Eassie whose establishment happened to be near to Tredwells' premises (5). No doubt this fortuitous location was a factor in his selection but it is reasonable to assume that his machines were the best available; a driving rate of twenty piles per day was claimed and they were subsequently patented (6).

To provide gravitational force the ground work was set at an incline of 1 in 12 which, theoretically, would provide 1000 tons sideways load on the hull sufficient to launch it, so Brunel reasoned. Astride the ground work timbers were laid 12 inch square timbers at 2 feet intervals parallel to the hull on top of which was laid standard GWR railway line at 18 inch spacing at right angles to form the fixed part of the slide ways, giving a total of 80 rails per launch way. The underside of the launch cradles consisted of iron bars laid parallel to the hull 1 inch thick and 7 inches wide spaced at 11 inches. Upon these bars 6 inches of hardwood planking were placed on top of which came the framing of the cradles. Since the bottom of the hull was horizontal tapered wedges were driven between the hull and the hardwood over the bars to accommodate the wedge shape. On the extremes of the cradles, which supported the higher curved section of the hull, props were inserted and held in place by long bolts. There were 60 iron bars under each cradle. This gave 4800 contact points under each cradle thus 9600 in total to support an estimated 12000 tons. This equated to 1.25 tons at each contact point ; uniform load distribution was assumed. A diagram of the arrangement is shown in Figure 1.

To cover the possibility that gravity alone would be insufficient to move the inert mass, additional force would be available from hydraulic rams and barges moored in the river. Control of the expected rapid slide into the Thames was effected by two huge checking drums attached to the launch cradles by means of stud link anchor chain wound around the drums. Prior to the first launch attempt planned for November 3rd 1857 Brunel was confident that his arrangements would be successful and he writes to the E.S.N. Directors that the ship would require little effort to push her down the launch ways (7). Unknown to him however, they had cashed in on the opportunity afforded by the forthcoming spectacle and sold tickets for admission to the site. When the day arrived, the shipyard and its surrounds took on a carnival atmosphere as the crowds gathered to witness the event, this was not what Brunel had planned, but there was no alternative, the launch had to go ahead. From a specially constructed platform, high above the expectant onlookers, a prearranged flag signal was given and the launch procedure was underway. Just after mid-day, fastenings on the bow and stern were released, the chains on the checking drums slackened off and hydraulic pressure applied to the rams together with a pull from the barges moored in the river. What happened next was not quite in accordance with the plan, the ship slid down the ways, taking up the slack in the chains and rotating the checking drums before the brakes could be applied. The ship moved about four feet. It was the first and only time it would slide of its own accord, all subsequent movement would be by means of hydraulic rams of ever increasing size and concentration. It is not clear if the sliding was arrested by the braking or friction of the slide ways, the subsequent events suggest the latter; whatever the reason the long-awaited and hoped for success had been a disaster and would cost the E.S.N. dearly, both in money and public image. The subsequent struggle to get the ship into the water would take another three months and require a battery of hydraulic rams yielding a total of 3500 tons force to add to the 1000 tons afforded by gravity. Success came at last on the 31st January 1858 when, on the morning tide, the Great Ship became waterborne. An exhausted Brunel went on holiday whilst the E.S.N. filed for bankruptcy. Undoubtedly the project was in a precarious situation and, unsurprisingly, had become an object of ridicule in the newspapers. All was not lost however and although it would take almost two years, the Great Eastern was completed, embarking on her trial voyage on the 7th September 1859; I.K. Brunel died eight days later, aged 53.

**The Launch - what went wrong?**
Of the many misfortunes which characterised the career of the Great Eastern it is probably the protracted drama of the launch by which she is best remembered. A plethora of articles and books has appeared over the years, many by established authors, usually expressing the generally held view that friction in the iron launch ways was the root of the problem. Yes, friction was part of the problem, but no writer has attempted an explanation as to why this might be so. In theory it should work, so why did it not for Brunel ? We would not expect that an engineer of his stature and experience would make any design errors, after all one of his many strengths was attention to detail and his preparations were very thorough indeed. Fortunately the design and construction of the launch ways and cradles is well documented (8) and a detailed examination of the significant features and assumptions is therefore possible. From such a study it is evident that there were several factors mitigating against a successful controlled launch which, when in combination, made such a launch impossible.

Firstly, the assumption that the weight of the hull would be evenly distributed across the 9600 points of contact on the iron rails. In practice this is unachievable with a rigid system, which was effectively what had been engineered at the launch site. The use of wedges to transfer load from the flat bottom of the hull onto the iron strips would lead to large compressive forces being generated such that when the build staging was removed the bulk of the weight on the cradles would be transferred through the bottom. Because of the complexity of the cradle timberwork, the load transferred to the outer sections would be totally indeterminate, there being many joints and long timbers which would, when loaded, move slightly and change the loadings, unlike the wedges which would already be firmly located in compression. It is very likely therefore, that as a result of all these uncontrollable variables the actual loadings at each contact point would differ considerably and most likely be highest under the flat section of the hull. The assumption of uniform loading is cannot be substantiated with any certainty.

A second consideration is the manner by which Brunel supported the iron rails on the launch timbers. Standard G.W.R. rail section was used (9) this was flat bottomed and of shallow depth, the so-called "Bridge" rail, not the best shape to resist bending. For railway use it was continuously supported by baulks of timber, the so called "baulk road" of the G.W.R. Surprisingly Brunel chose to support the rails on 12inch square timbers at 2feet spacing
Thus lacking continuous support and with a point load of 1.25 tons at the centre of the suspended length, a measurable deflection could be expected. In other words, if the loads were much higher further bending of the rails would result in a considerable increase in friction as the iron strips under the cradle tended to dig in. In fact a contemporary account noted that some of the rails had actually been forced into the timber supports (10) this indicates that the loads in some areas must have been very high indeed!

The third factor in the equation is the matter of lubrication. For wooden launch ways, a suitable grease is spread over the fixed ways prior to launch. To prevent the grease being squeezed out during the launch the dimensions of the ways are chosen such that the contact pressure does not exceed 30lbs. per square inch (11) and of course the static and moving parts are in continuous contact. Although this is contemporary practice, experience would have dictated something similar in Brunel's day. Applying this criterion to the iron ways we find that the contact pressure is ten times higher (12) also to exacerbate the situation the shearing action of the iron plates, at right angles to the rails, would immediately remove most of the lubrication. It is apparent that Brunel expected this to happen ; he commissioned a series of experiments on a small scale test rig using varying amounts of lubricant, including none at all, with a fixed loading representing the assumed launch condition. The results suggested that friction would not be outside the expected range, but did not provide any data on the effect of increase in loading at the sliding faces, this latter being the heart of the problem (13).

With these mechanisms in play the launch could never be the success that had been planned. Even Brunel had no idea how much force would eventually be needed. At one stage the stability of the launch ways was questioned, so a test load was applied to a section of the ways but no movement was detected (14). What had happened was, with loadings in some areas well in excess of those assumed, the rails were bending between the supporting timbers and forming undulations, resulting in the iron strips under the cradles digging into the rails. This would of course increase considerably the resistance to movement. More force was required so it was necessary to increase the number of hydraulic rams. Tangyes of Birmingham rallied to the cause and mainly due to their efforts the battle was won, the role they played subsequently enabled them to claim "We launched the Great Eastern and she launched us"

It is a perplexing enigma that Brunel spurned all advice and decided against wooden launch ways, it was a costly misjudgement. Although the mass to be moved was the largest ever constructed in wrought iron, the area of timber available to give continuous support for a conventional launch way was more than adequate. Even with the primitive tallow-based grease of the era, Brunel's fears were unfounded, a first-time launch could have been accomplished.

**The aftermath**

The Great Eastern languished at her moorings in Deptford for almost a year before a new organisation-The Great Ship Company- was formed to complete her. The first voyage was not without drama, a feed water heater exploded, killing five stokers. Ever after she was regarded as being jinxed a reputation which she lived up to with a series of accidents throughout her career.

In recent years focus on our industrial heritage has resulted in greater emphasis on preserving some of what is left of our past achievements. It is fitting therefore that the Great Eastern launch site on the Isle of dogs has not been neglected. Some twenty years ago developers of the site at Millwall excavated a section of the launch ways which are now presented as a heritage site. Tredwells' work is still in position for all to see and well illustrate the gigantic scale of the operation. Solomon Tredwell, who appears to have been site manager for their contract, is also recorded for posterity as he is standing alongside Brunel in one of the series of photographs taken at the time of the launch. He too would die prematurely, in India in November 1859 aged 40, whilst engaged on a railway contract which, interestingly, was completed by his wife Alice (15). Following the death of other partners the Gloucester connection was severed when the yard was closed and offered for sale in 1862 (16). William Eassie died in 1861, the business continuing under the direction of his sons. This too came to an end in 1875 (17) and thus the business names associating Gloucester with the Great Eastern steamship were consigned to the archives of Industrial History.

**References**


1 The Times, 1 September 1852.
2 Hollingworth Collection, Bath University, letter from Yates to Brunel, 7th October 1856.
3 Hollingworth Collection, Contract for launching ways, undated.
4 Life of Isambard Kingdom Brunel (1870) p.344.
5 Gloucester Docks, An Illustrated History, Hugh Conway-Jones, Alan Sutton 1984, Page 60.
6 British Patent No. 1378, 1865. Gloucester Journal 14 February 1857.
7 Life of Isambard Kingdom Brunel (1870) p.352
8 Ibid p. 345-347,also The Great Eastern Steamship, London, H.G,Clarke & Co., 252,Strand.
9 We do not know what size rail was used, it would however, be of wrought iron. Based on samples of later steel "Bridge" rail the section is only 3 inches deep, see attached diagram. With a point load of 1.25 tons a deflection of 0.02 to 0.04 inches could be expected with the rails supported at 2 ft Spacing.
10 S.S. Great Eastern, George S. Emmerson, David & Charles, 1981. Page 41.
11 Ship Construction, D.J. Eyres, Heinemann, London 1972. The value quoted is 20 tonnes per sq. metre which is almost 30 lbs per sq. inch.
12 G.W.R. "Bridge" rail was 2 inches wide on its top surface, the iron strips under the cradles were 7 inches wide so the contact area would be 14 sq. inches under optimum conditions. With the assumed even loading of 1.25 tons this gives a contact pressure of 200 lbs per sq. inch.
13 Life of Isambard Kingdom Brunel (1870) Pages 385-389.
14 Ibid Page 367.
15 Mechanical Engineering News, June 1980, Institution of Mechanical Engineers.
16 Gloucester Journal 12 July 1862.
17 William Eassie- A notable Victorian Contractor, Hugh Conway-Jones, G.S.I.A. Journal 2004 pp 53-58.

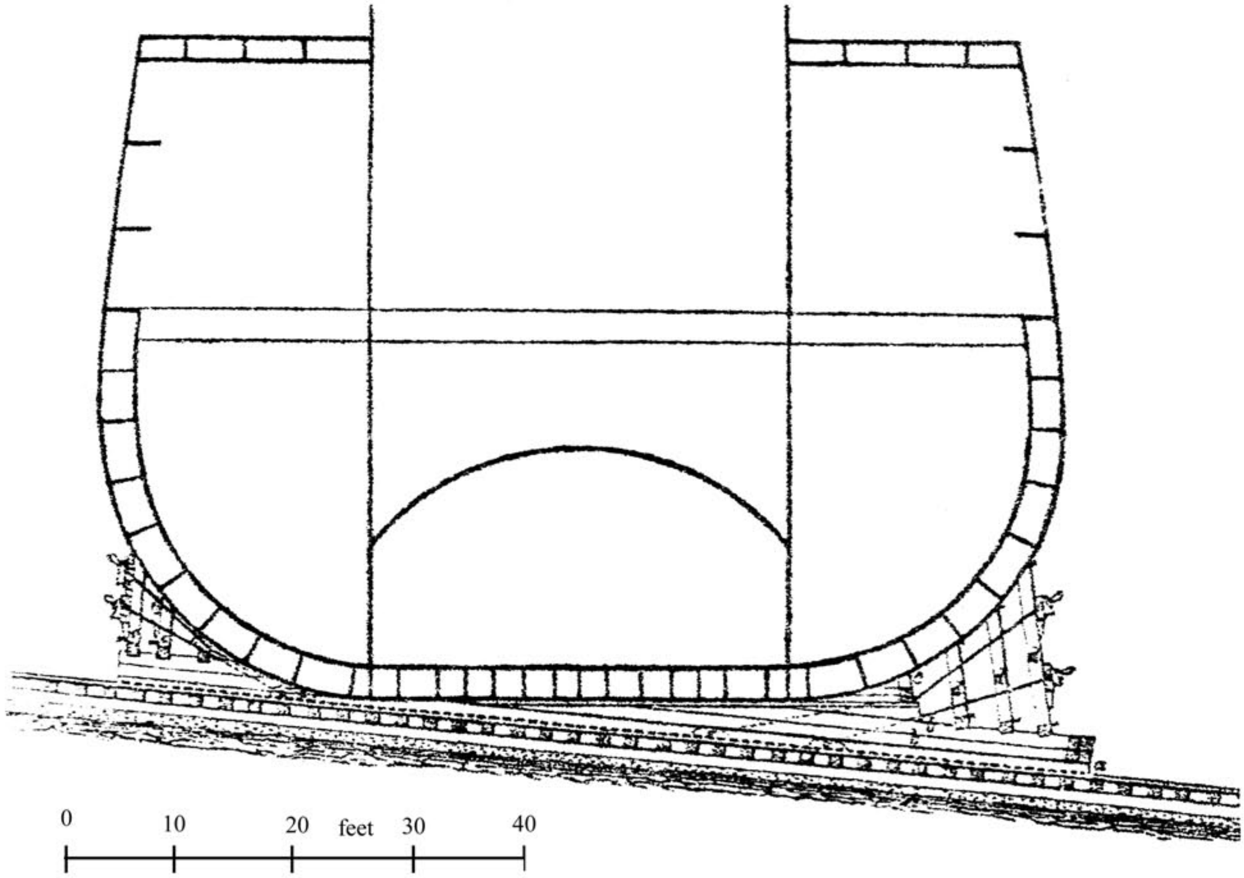


Fig 1. Transverse Section of Ship Showing Ways and Cradles

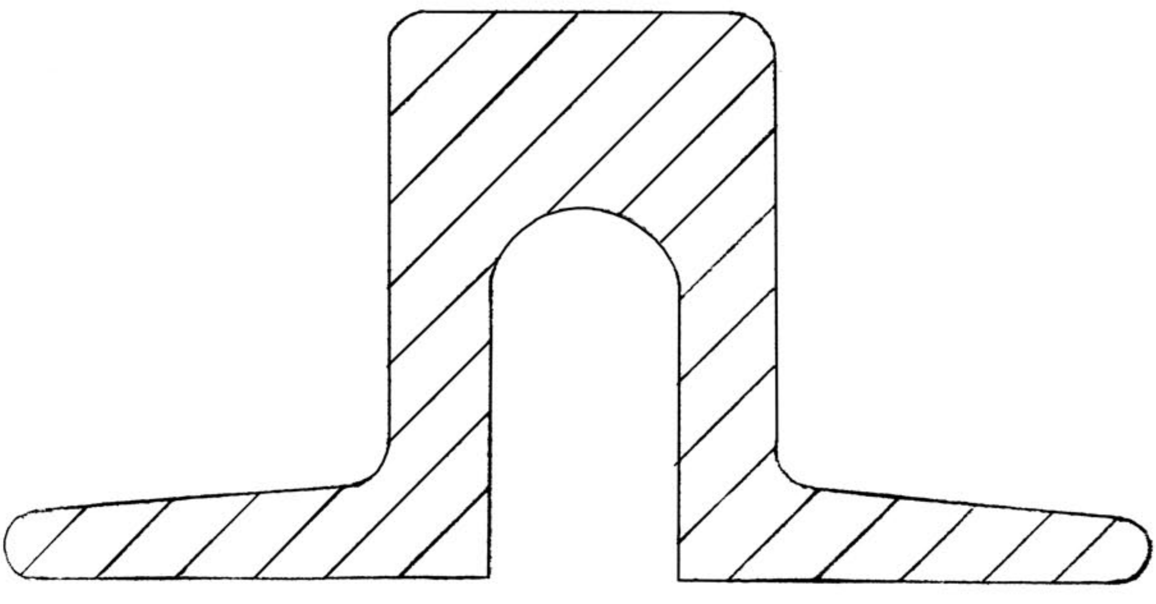

Fig 2. G.W.R Bridge Rail Scale: Full Size.

This was the standard steel rail used for the broad gauge for the later years of the 19th Century. This would not have been available in Brunel's time. He may well have used a smaller section in wrought iron, there were several sizes, which would have even less resistance to bending.