Boat lifts in the UK

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Abstract. Once upon a time England's canals and rivers were the motorways of their days and all sorts of goods were transported from one end of the country to the other. These days canals and rivers are generally used for recreational pursuits but raising and lowering boats from one level to another, be it on the same waterway or between two different waterways, still remains an engineering issue. This paper looks at three very different boat lifts found around the UK: the Anderton Lift, described as the "cathedral of the canals" was opened in 1875 and still survives today; The Foxton Lift in Leicestershire was built in 1899 and only saw a few years' service; and the most recent acquisition to the canal network, The Falkirk Wheel in Scotland, which opened in 2002.

1 INTRODUCTION

At one point the canals and rivers of the UK were the motorways of the time and cargo was transported up and down the country in working boats. Famous companies such as Fellows Morton & Clayton were formed and had fleets of working boats upon which whole families would live in the traditional back cabin measuring less than 10ft long and in which you had to cook, wash and sleep. The children, who were mostly uneducated due to the nomadic lifestyle of their families, often slept on top of the cargo being carried. Many boats increased their carrying capacity by double breasting or towing a "butty" which was essentially a boat with no engine. The early canals were "contour canals" and would stay at the same height for miles on end thus negating the need for locks. This was very often a long and torturous way of covering just a few miles. Locks were installed to raise and lower boats but these were time consuming especially if you arrived at a lock that was against you (water level not set so you can enter the lock immediately). In some cases flights of locks were built where one gate was the top gate for one lock and the lower gate for another. Passage through flights of locks was costly and places such as the Caen Hill flight near Devises in Wiltshire on the Kennet & Avon Canal (see fig 1) could take a day to get from top to bottom or vice versa. The answer was a boat lift and there are 3 famous lifts ranging from Victorian times to a relatively modern installation in Scotland.

Fig 1: Caen Hill Locks

2 THE ANDERTON LIFT (1875)

Initially a flight of locks was considered for the task but this was discounted due to the time it would take boats to passage, the amount of space required and the large amount of water that would be lost from the canal to the river.

The Anderton Boat lift (see Fig 2) is often referred to as the "Cathedral of the Canals" and was designed by Edwin Clark. It was built in 1875 and was built an impressive 60 feet high, allowing it to clear the 50-foot difference in height between the two water levels of The River Weaver and the Trent & Mersey Canal. The entire structure was 85 feet long and 49 feet wide, while the aqueduct was 165 feet long. Each tank or caisson weighed a staggering 91 tonnes empty and 252 tonnes when flooded. These giants were 75ft long, 15 feet 6 inches wide, and 9 feet 6 inches deep in the middle. They were big enough for 2 narrow boats.

Fig 2: The Anderton Boat Lift

In 1908 the addition of a machinery deck brought the overall height to 80 feet, while the A-frames added for support widened the lift to 75 feet at its base. Each tank was counterbalanced by 252 tonnes of cast iron counterweights, attached by wire ropes. This gave a balance of 1:1. There were 36 stacks of counterweights on each side, weighing 7 tonnes each. The lift boasted 72 geared pulley wheels in all, and the largest ones, which took the lifting and safety ropes, weighed 3.5 tonnes each. There were 8 on either side. There were a further 20 pulley wheels taking 2 lifting ropes each, and 36 wheels with one lifting rope each. The shafts bearing the pulleys were 8 inches in diameter and the pulley pedestals weighed in at between 193 and 466lbs each. All in all, a good breakfast for the fitter weighing in all the scrap!

In 2001 the lift was restored to full hydraulic operation. The 1908 structure and pulley wheels were retained as a static monument.

The replacement hydraulic ram shafts replicate the original 3-foot diameter rams and are 56 feet long when retracted and 106 feet long when fully extended. The ram shafts are 56ft deep. Each ram weighs approximately 50 tonnes.

Edwin Clark, the designer of the lift, went on to design bigger lifts on the Continent including the lifts at La Louviere in Belgium.

3 THE FOXTON BOAT LIFT (1901)

The Foxton Inclined Plane (see Fig 3) was installed on the Leicester Branch of the Grand Union Canal. The Lock flight at Foxton was built in 1810, and the top summit route opened four years later, celebrating its anniversary in August 2014. A trip through the ten locks takes about 45 minutes to negotiate the 75 ft (just under 23 metres) hill and uses 25 thousand gallons of water, but if there is a queue you can be held up for hours. In the days when canals were used as a means of transporting cargo and were significantly busier than their relatively new use for leisure this could be bad for business. Boat width in the locks is restricted to seven feet so working boats with a “butty” would have to negotiate the flight separately. Boats using the locks were restricted to a maximum load of 20 tons. A solution was needed!

With the coming of the railways, competition was starting to bite. Fellows Morton and Clayton (FMC) wanted to use bigger boats to take coal from the north to the London factories. They promoted a take-over of the Leicester line of the canal by the Grand Junction Canal Company. The takeover was successful and FMC promised to put more narrowboats on the canal until the locks at Watford Gap and Foxton could be widened. GJCCo engineer Gordon Cale Thomas was put in charge of the project however wide locks were dismissed as using too much water from the canal's summit pound. His solution was to build a boat lift to his patented design.

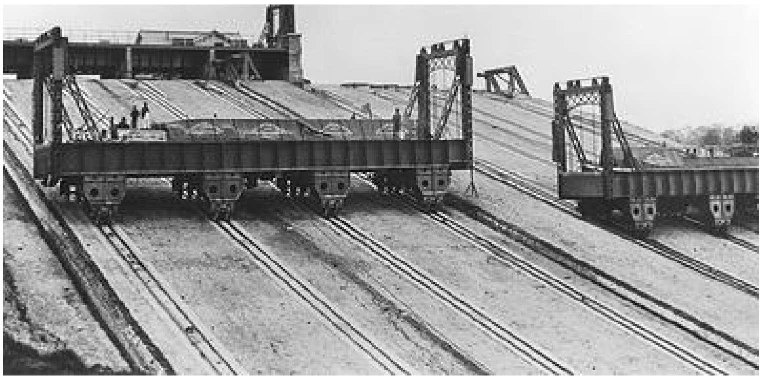

Fig 3: Foxton Inclined Plane under construction

The lift was built in 1901 by J & H Gwynne of Hammersmith, London. They got the job as they proposed using hydraulic power for the gates and ancillary equipment. It consisted of two tanks or caissons linked by wire rope (see Fig 4). A steam driven winch at the top wound the rope on to one side of its drum and simultaneously let it off the other, raising and lowering the tanks. Each tank was full of water and weighed 230 tons with or without a boat as boats displace their own weight in water. Two boats could fit in to each tank. The gradient of the system was 1 in 4. At the top level the caisson was hauled over a slight hump thus taking the weight off the system and also allowing the bottom caisson to overcome being suspended in the water at the bottom.

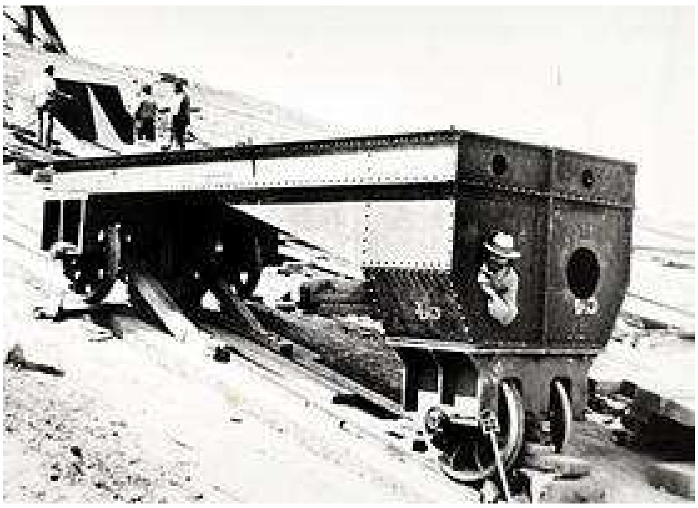

Fig 4: A caisson under construction

Its operation was fairly simple. Assuming your boat is at the bottom, you took your boat(s) into the tank. The operator would close a guillotine gate behind you and signal the engine room with a ship's telegraph. The 25 horsepower steam engine was turned on and you ascend the hill. The other tank descends either loaded with boats or just full of water. The descending tank simply sinks into the water at the bottom where the guillotine gate is opened by the operator. However, the immersion of the descending tank effectively makes it lighter in weight, upsetting the balance between the two tanks. To compensate for this, when the tank nears the top of the Incline, an ingenious change is made to the angle of ascent. The top of the slope curves off, effectively making it easier for the tank to ascend. On the leading edge of the tank, extra wheels come into contact with extra rails either side of the normal track. At the same time the rear wheels descend into a pit. This arrangement keeps the tanks upright. The tank has wooden seals fixed on the end of each top dock. Once at the top, hydraulic rams push the tank on to the wooden seal, and the guillotine gates on the end of the tank and on the dock are opened. The horse is re-attached and off you go. The entire operation took 12 minutes, and could move 2 boats up and 2 down. A big saving against the time taken to use the locks. The lift also saved a tremendous amount of water, because the only water lost was that trapped between the gates at the top.

The lift had worked well but the locks at Watford Gap were never widened, and the traffic didn't increase as railways were the new mode of transport. This made the lift uneconomic. There were problems with track bolts pulling out of the sleepers, but nothing that could not have been overcome. The lift was capable of moving a massive amount of traffic compared with the actual usage. FMC's promise of increased traffic hadn't been fulfilled. In 1911 the lift was mothballed to save money, the traffic returning to the locks which have been in use ever since. The decision was probably due to the need for substantial maintenance repairs on the 10 year old structure - it probably needed new cables which are expensive and the cost of keeping the lift in steam with a minimum of three operators. The fact that a fully working set of locks was available alongside the lift would not have helped. The lift was maintained for a few years, surviving the first world war, and sank into a slow decline. In 1928 the machinery was sold for scrap.

4 THE FALKIRK WHEEL

The Millennium Link was an ambitious £84.5m project with the objective of restoring navigability across Scotland on the historic Forth & Clyde and Union Canals, providing a corridor of regenerative activity through central Scotland.

Fig 5: Falkirk Wheel during operation

A major challenge faced was to link the Forth and Clyde Canal, which lay 35m (115ft) below the level of the Union Canal. Historically, the two canals had been joined at Falkirk by a flight of 11 locks that stepped down across a distance of 1.5km, but these were dismantled in 1933, breaking the link.

What was required was a method of connecting these two canals by way of a boat lift. British Waterways (now Scottish Canals) were keen to present a visionary solution taking full advantage of the opportunity to create a truly spectacular and fitting structure that would suitably commemorate the Millennium and act as an iconic symbol for years to come.

The various parts of The Falkirk Wheel (see Fig 5) were actually constructed and assembled, like one giant Meccano set, at Butterley Engineering's Steelworks in Derbyshire. A team there carefully assembled the 1,200 tonnes of steel, painstakingly fitting the pieces together to an accuracy of just 10 mm to ensure a perfect final fit.

In the summer of 2001, the structure was then dismantled and transported on 35 lorry loads to Falkirk, before all being bolted back together again on the ground, and finally lifted by crane in five large sections into position. The total 600 tonne weight of the water and boat filled gondolas imposes immense and constantly changing stresses on the structure as it turns around the central spine. Normal welded joints of steel would be susceptible to fatigue induced by these stresses, so to make the structure more robust, the steel sections were bolted together. Over 15,000 bolts were matched with 45,000 bolt holes, and each bolt was hand tightened.

The result is a perfectly balanced structure that is The Falkirk Wheel. Completion of The Millennium Link project was officially marked by Her Majesty The Queen on 24 May 2002.

The Falkirk Wheel (see Fig 6) lies at the end of a reinforced concrete aqueduct that connects, via the Roughcastle tunnel and a double staircase lock, to the Union Canal. Boats entering the Wheel's upper gondola are lowered, along with the water that they float in, to the basin below. At the same time, an equal weight rises up, lifted in the other gondola.

This works on the Archimedes principle of displacement. That is, the mass of the boat sailing into the gondola will displace an exactly proportional volume of water so that the final combination of 'boat plus water' balances the original total mass.

Fig 6: Falkirk Wheel

Each gondola runs on small wheels that fit into a single curved rail fixed on the inner edge of the opening on each arm. In theory, this should be sufficient to ensure that they always remain horizontal, but any friction or sudden movement could cause the gondola to stick or tilt. To ensure that this could never happen and that the water and boats always remain perfectly level throughout the whole cycle, a series of linked cogs acts as a back up.

Hidden at each end, behind the arm nearest the aqueduct, are two 8m diameter cogs to which one end of each gondola is attached. A third, exactly equivalent sized cog is in the centre, attached to the main fixed upright. Two smaller cogs are fitted in the spaces between, with each cog having teeth that fit into the adjacent cog and push against each other, turning around the one fixed central one. The two gondolas, being attached to the outer cogs, will therefore turn at precisely the same speed, but in the opposite direction to the Wheel.

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BIOGRAPHY

David Cooper has been in the lift industry since 1980 when he started an apprenticeship with British Railways. He has been involved with many of the rail mounted inclined lifts around the UK including Hastings East, Hastings West, Babbacombe, Scarborough Central, Scarborough South Cliff, Scarborough St Nicholas, Padstow, Lizard, Southend, Urbis Centre, Machynlleth, Bridgnorth. Internationally he has also been involved with the Angels Flight inclined lift in Los Angeles. In 2008 he appeared in the BBC programme “Flog It” as the expert showing Paul Martin over the Inclined Lift at Babbacombe in Devon. He has won awards for his involvement with inclined lifts including the Association for Consulting and Engineering Awards for the projects at Babbacombe and Hastings. He has also been involved with aerial suspended cableways and was the winning project in the Elevator World Project of the Year in 2013 for the London Emirates Airline Cable Car on which he presented a paper at the 2013 Symposium.