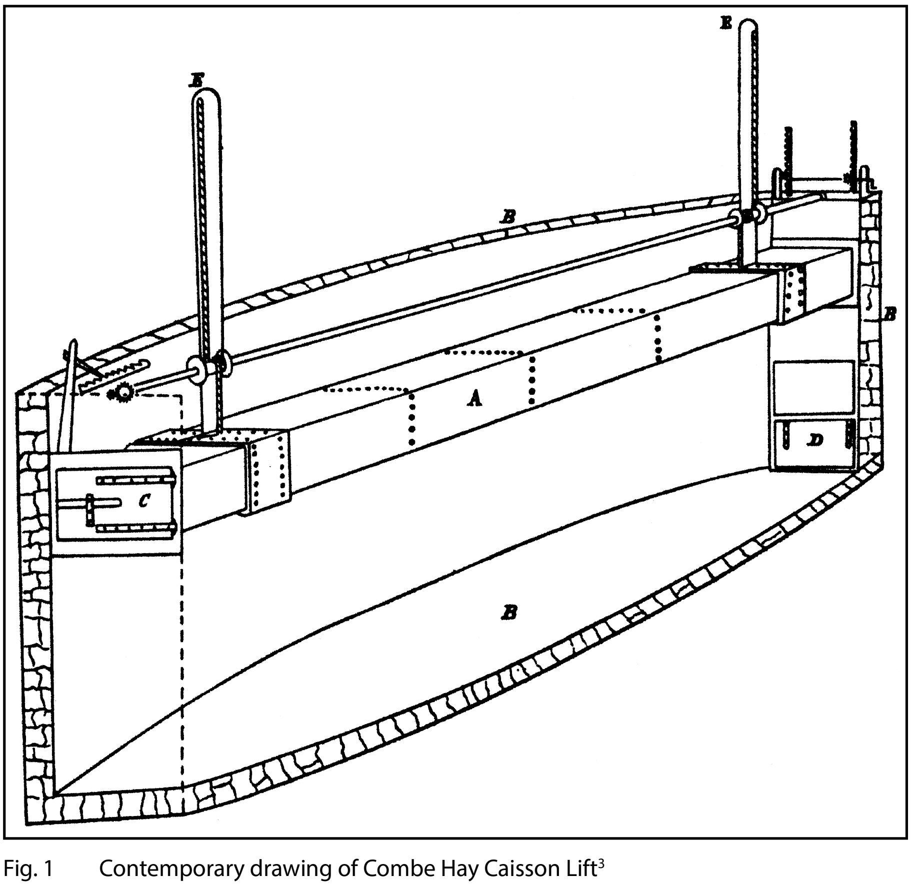


Fig. 1 Contemporary drawing of Combe Hay Caisson Lift[3]

COMBE HAY TO FALKIRK

The evolution of the Canal Lift

Terry Paget

BIAS Brunel Prize Essay 2000

Introduction

The sight of a 500 ton caisson majestically and silently raising a 400 ton boat in water 60 feet between canal levels is a wondrous spectacle. Achieving this proved difficult, and for forty years all attempts to build commercial boat lifts ended in failure. Technology improved, men persevered, and in 1836 the first commercial canal lifts entered service. Since 1840 canals have fallen into decline, replaced first by railways, then by roads. Yet canal lifts have continued to be built. At the time of writing nine are working in the world, and there are two under construction. This essay plots their evolution, from the brilliant but unfortunate Somerset Coal Canal Caisson Lift of 1792 to the futuristic Falkirk Wheel under construction in Scotland. Some of the lifts described are not in the old county of Avon, but most of the early ones were in Somerset. The author has visited a majority of the working examples in day trips from Midsomer Norton.

The first recorded means used of raising boats between levels was by inclined plane. In 1700 BC the Ancient Egyptians used slaves to haul boats up a slope to avoid rapids on the River Nile between Mirgissa and Abusir Rock. The slipway was about two miles long, slightly curved in section, with cross pieces of wood every 18 inches or so; Nile silt was used as lubricant. Until recently the slipway could still be seen, showing a depression in the centre where the keel of the boat slid; sadly, it now lies beneath the waters of the High Aswan Dam.[1]

Locks were an obvious method of raising boats between levels on river navigations, where ample water was available. When they were first used is not known, but they became established as the standard technique of changing levels on canals when the Languedoc canal was opened in France in 1681[2]. This canal was over 200 kilometres long, and joined the Atlantic Ocean and the Mediterranean by crossing the southwest corner of France between Bordeaux and Narbonne. It was this canal that the Duke of Bridgwater visited, and which so impressed him that he returned to England and built a canal to serve his coal mines at Worsley, which in turn led to the canal building mania in Britain in late eighteenth century.

Britain is a small island, so has few major rivers. As the home of the Industrial Revolution it had a great need for bulk transport, so built canals on a grand scale. Water was often scarce and required pumping, so means of changing levels were sought less wasteful of water than locks. Inclined planes were used occasionally, but the technology available tempted plucky engineers to attempt vertical lifts.

Robert Weldon's Hydrostatic Caisson Lift

In 1792 Robert Weldon patented his "Hydrostatic Caisson" Lift. He built a half size demonstration model somewhere in Shropshire, site now lost, and persuaded the Somerset Coal Canal to build a full sized lift at Combe Hay, near Bath.[4] The problem with any canal lift is to support, raise and lower the massive vessel - the caisson - containing boat and supporting water. In Weldon's narrow boat lift it would have weighed 50 tons. To achieve this he immersed the all-enclosing caisson in a cistern of water, ballasted it to be weightless, and raised and lowered it with rollers and chains, as shown in the accompanying contemporary drawing[5]. Apparently this arrangement worked well, and it is reported that a boy of 12 could raise and lower the caisson. What this drawing does not depict are the means of keeping the caisson horizontal. The caisson was a long vessel containing open water and was thus unstable, a slight tilt either way causing the water to flow to the lower end adding to the tilting force. The vertical masts (E) have been described as parallel motion devices by some recent authors, the legend properly describing them having been lost, but this is a duty they are quite unfit to bear. Their function was simply to allow the chains to raise or lower the weightless caisson which was kept level with wheels or rollers on the ends of the caisson running up and down tracks or rails attached to the ends of the cistern. This must have been effective, because on good days the lift worked. The trouble was that the runners would have been set up parallel and vertical with the cistern drained, and then were expected to remain to dimension with the cistern filled.

A trial on 12 February 1798 before a large crowd of people resulted in disaster when one of the stabilising wheels broke off letting the caisson down at one

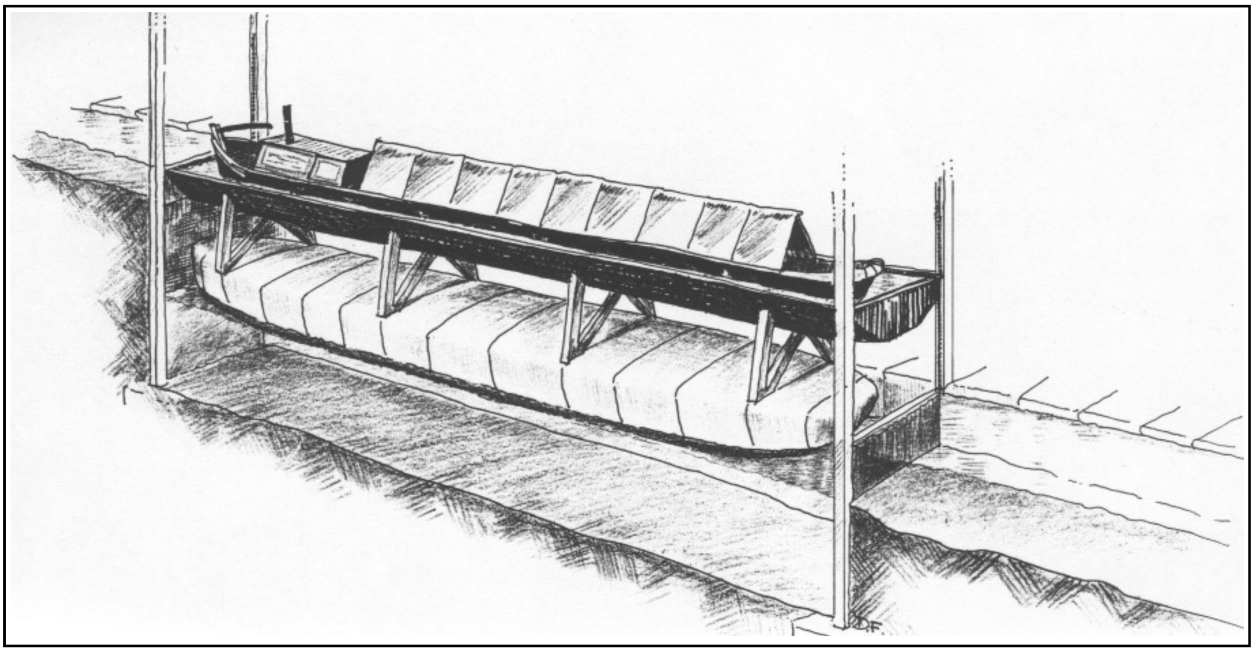


Fig. 2 Rowland & Pickering Float Lift of 1796. Showing the float before submersion. Drawing by David Fisher 2000

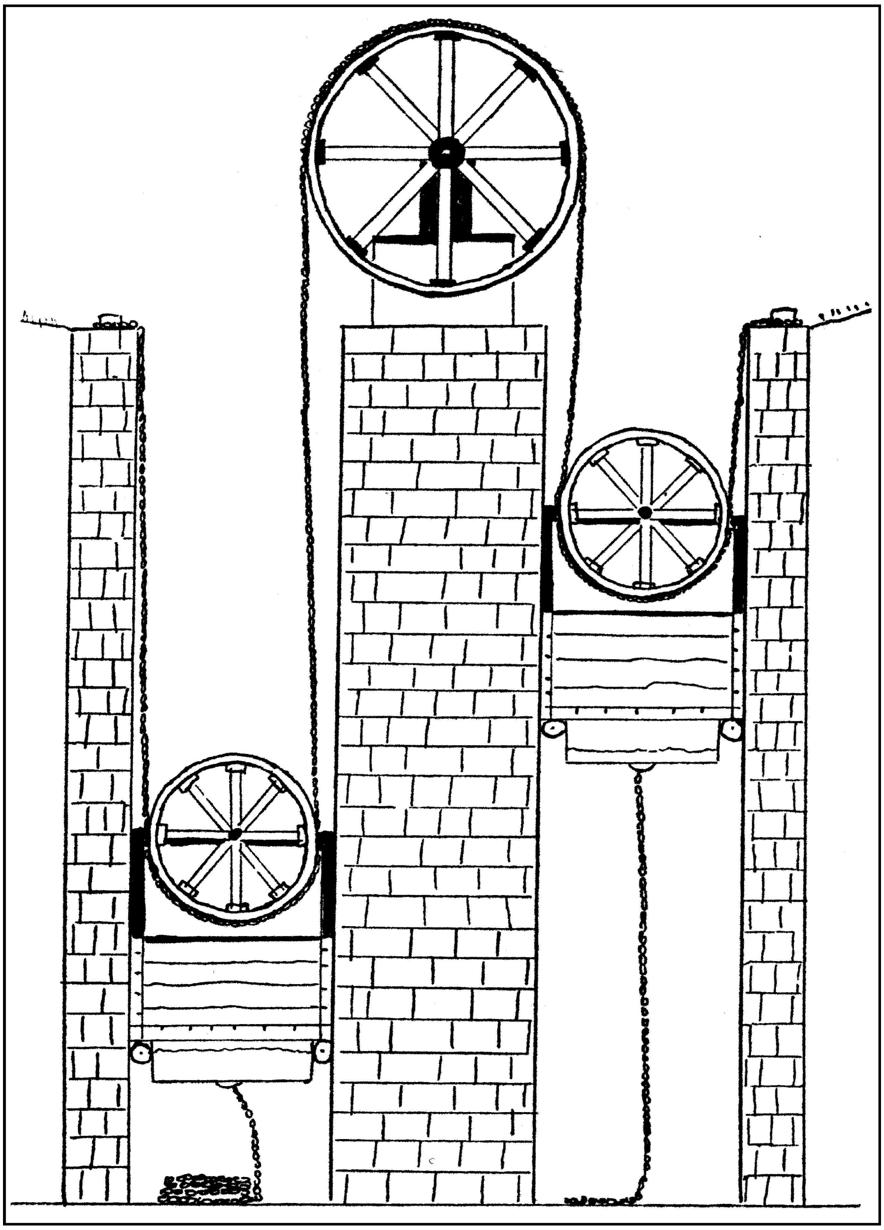


Fig. 3 James Fussell's Balance Lift, Mells 1800

end.[6] Repairs were carried out, and a further trial was carried out satisfactorily on 4 June 1798. The lift acquired fame throughout the land, and in April 1799 the Prince of Wales spent a wet Saturday admiring it rising and descending. He did not himself ride in the caisson, but he did send one of his staff up in it to convince himself that it did actually convey a boat between levels. However, further trials were carried out, further repairs made, but owing to unstable geological conditions the lift could not be made reliable for regular service and it was finally abandoned in late 1799.

Today, despite digs by Angus Buchanan,[7] Adrian Tuddenham,[8] Mike Chapman and others,[9] research by Hugh Torrens,[10] Roger Halse and many others, the caisson has not been found and may never be. For a lift that failed and was abandoned 200 years ago it still inspires surprising interest and activity. The design has never been copied.

Rowland & Pickering

In 1793 Edward Rowland and Exuperius Pickering[11] patented a similar canal lift, with one caisson able to accommodate a narrow boat, again supported by water, but this time with a large float immersed in water beneath the caisson which carried it on an iron and wooden framework. The design was offered to the Ellesmere canal proprietors, who doubted its efficacy. The inventors agreed to build it at their own expense, on the understanding that the Canal Company would pay for it if it proved successful. In May 1796 it was announced that it was available for inspection. Little more has been heard of it, though in the canal accounts of 1800 £200 was paid to the inventors to defray half their expenses. The site of this interesting experiment is now lost. The idea was nevertheless sound, and it was copied at Henrichenburg a century later.

James Fussell's Balance Lock[12]

In 1798 James Fussell, ironmaster of Mells, in Somerset, patented the first balance lift, a design of lift with two caissons coupled together so that as one rose the other fell. The desired motion was achieved by making the upper caisson heavier then the lower by adding water to a tank beneath the caisson, and releasing the brake. The caissons were coupled by fixed chains, as shown in the drawing, with chains attached below the caissons to counterbalance the varying weight of the support chains. A test lift was built at the top of Barrow Hill, near Mells, on the Dorset and Somerset canal, and was demonstrated on 6th September 1800, to the satisfaction of the local press. The lift raised ten-ton tub boats twenty feet. Four more lifts were started, but the canal ran out of money, and construction ceased in 1803. The design had been a good one, and led the way for the next eighty years.

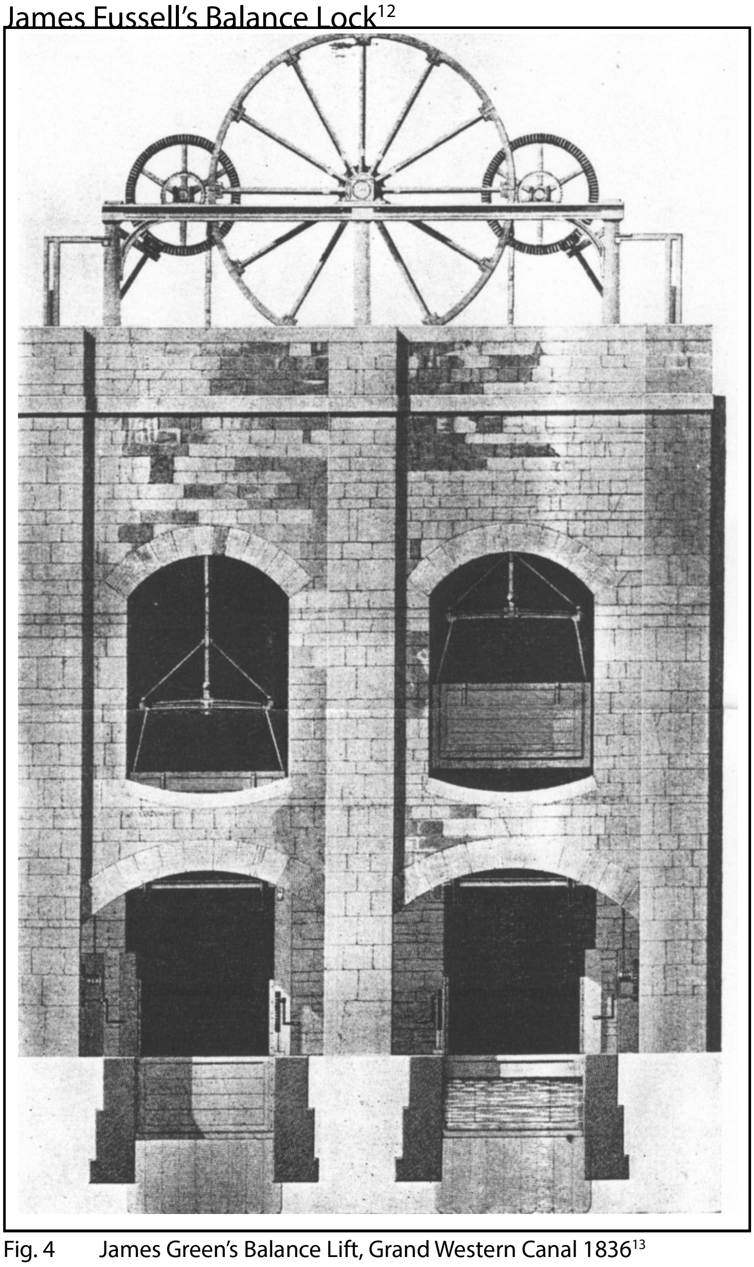


Fig. 4 James Green's Balance Lift, Grand Western Canal 1836[13]

The Grand Western Lifts

In 1830 the Grand Western canal proprietors decided they would extend their canal, already trading between Exeter and Tiverton, from Tiverton to Taunton, making connection with the Bridgwater & Taunton canal and thus joining the Bristol and English channels.[14] Their engineer, James Green, recommended a canal with no less than seven lifts, as well as an inclined plane at Wellisford. He unwisely offered to build these for the Canal Company at a fixed price, an offer that was accepted. The lifts proposed were similar to James Fussell's, with two balancing caissons supported by three chains as in the drawing. Fine adjustment of the positions of the caissons could be made using the handles and gears shown in the drawing. The boats to be raised were eight-ton tub boats, and the vertical lifts varied between 42 feet (Greenham) and 12 feet (Norton Fitzwarren).

Construction began in 1830 on all seven lifts, and by 1834 the Taunton lift was ready for testing. An unforeseen problem was discovered. The lift worked well as long as the chamber into which the caisson descended (the sump) remained dry of water. But as leaks filled it with water, the descending caisson descended until it settled in this water, at which point it came to rest, some four feet above lower canal level. There was no easy solution to this problem, and it is surprising that James Green had not foreseen it. In James Fussell's patent he planned to drain the sumps by adit, emerging lower down the hill. This solution presumed the existence of nearby lower ground, which was available for his test lift at the top of Barrow Hill, but would not have worked at the bottom lift had it been completed. All of James Green's lifts, except Greenham, descended to ground level, so could not be thus drained. The only solution was to build small locks below both caissons to lower the boats the four feet or so that the caissons would not descend by gravity.

The inclined plane at Wellisford did not work at all. It was a balanced incline, assisted with a bucket in a well system. Green had used a similar system on the Hobbacott great incline on his Bude canal, but there he used a 15-ton bucket to raise a five-ton boat. On the Grand Western he attempted to raise an eight-ton boat with a ten-ton bucket; it failed completely. James Green had met his Waterloo.

In 1836 James Green was replaced as engineer by the 80 year old Captain John Twisden, who proposed replacing the Wellisford inclined plane with thirty locks of a novel design.[15] He was persuaded not to pursue this idea, and instead to lend the Company £1000, allowing it to purchase a second hand 12 horse power steam engine, which worked the incline satisfactorily.

Hydraulic Lifts - Anderton

In the 1840s the use of high-pressure hydraulic power was developed, and became the standard way of moving heavy machinery in docks, harbours, shipyards, rivers and canals.[18] Water was pumped to high pressure and stored, then released through engines, rams or other devices to do work as required. Storage was initially achieved in tanks on top of tall towers, but this did not achieve as high a pressure as was ideal, so weighted accumulators - large vertical cylinders with large weighted pistons in them - became the norm, working at about 50 atmospheres pressure. Hydraulics were the obvious way to couple the caissons on a balance lift, and they were put to this use in a lift built at Anderton,[19] Cheshire, 1872-1875, linking the Trent & Mersey canal and the River Weaver. The engineer Edwin Clark still employed wet sumps, as on the Grand Western Canal, and for some reason, chose to use a steam engine to turn his pump, but the lift worked well from its opening in 1875. The caissons could accommodate two narrow boats or one Weaver flat. The boats were raised 50 feet by the lift, each caisson being supported by an hydraulic ram three feet in diameter. The wet sumps were a complication, but the hydraulics could cope with them. Problems were to follow as will be seen, but the lift was an initial success and trend-setter, and Edwin Clark advertised in four languages his availability as consultant engineer to anyone else wishing to build a similar lift.

Hydraulic Lift - Les Fontinettes, France

Clark's first commission came from France, where the five locks at Les Fontinettes, near St.Omer, on the canal du Neufosse, were causing serious

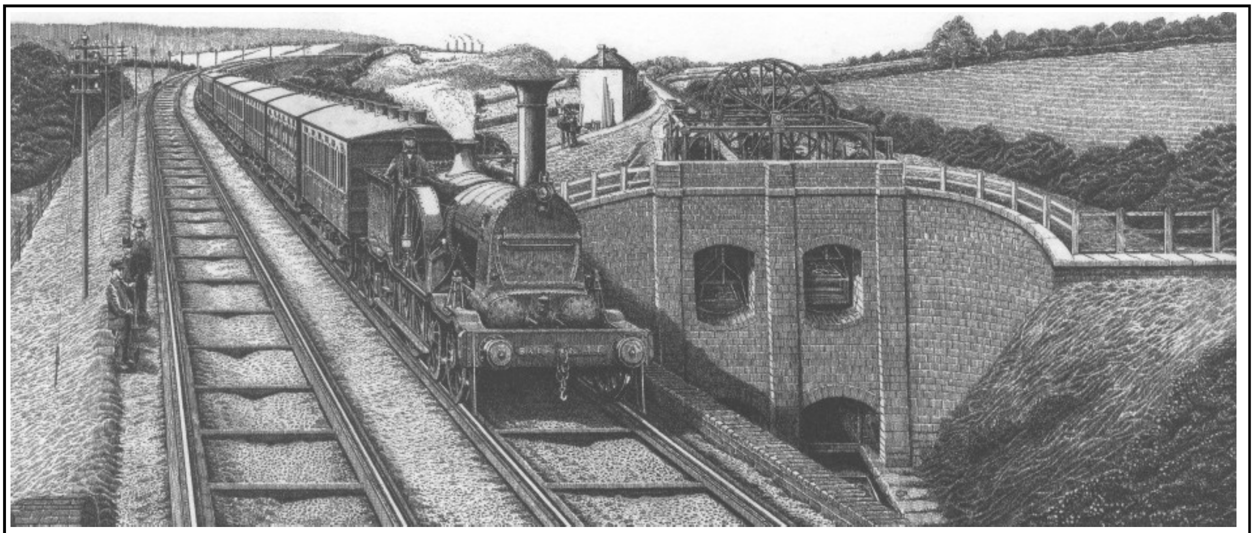


Fig. 5 Trefusis Bridge
Drawing by Simon Bowditch, 1996, showing the Bristol & Exeter Railway and the Grand Western Canal Nynehead Lift. Thus modified, the Grand Western eastern extension was operated from 1836. In 1848 the Bristol & Exeter Railway was opened between Taunton & Tiverton, leading to a financial crisis in the canal's affairs.[16] In 1853 the canal was leased to the railway, and in 1865 sold to the railway by Act of Parliament. In 1867 the Taunton-Lowdwells section of the canal was closed and dismantled. So ended the first successful use of the canal lift.

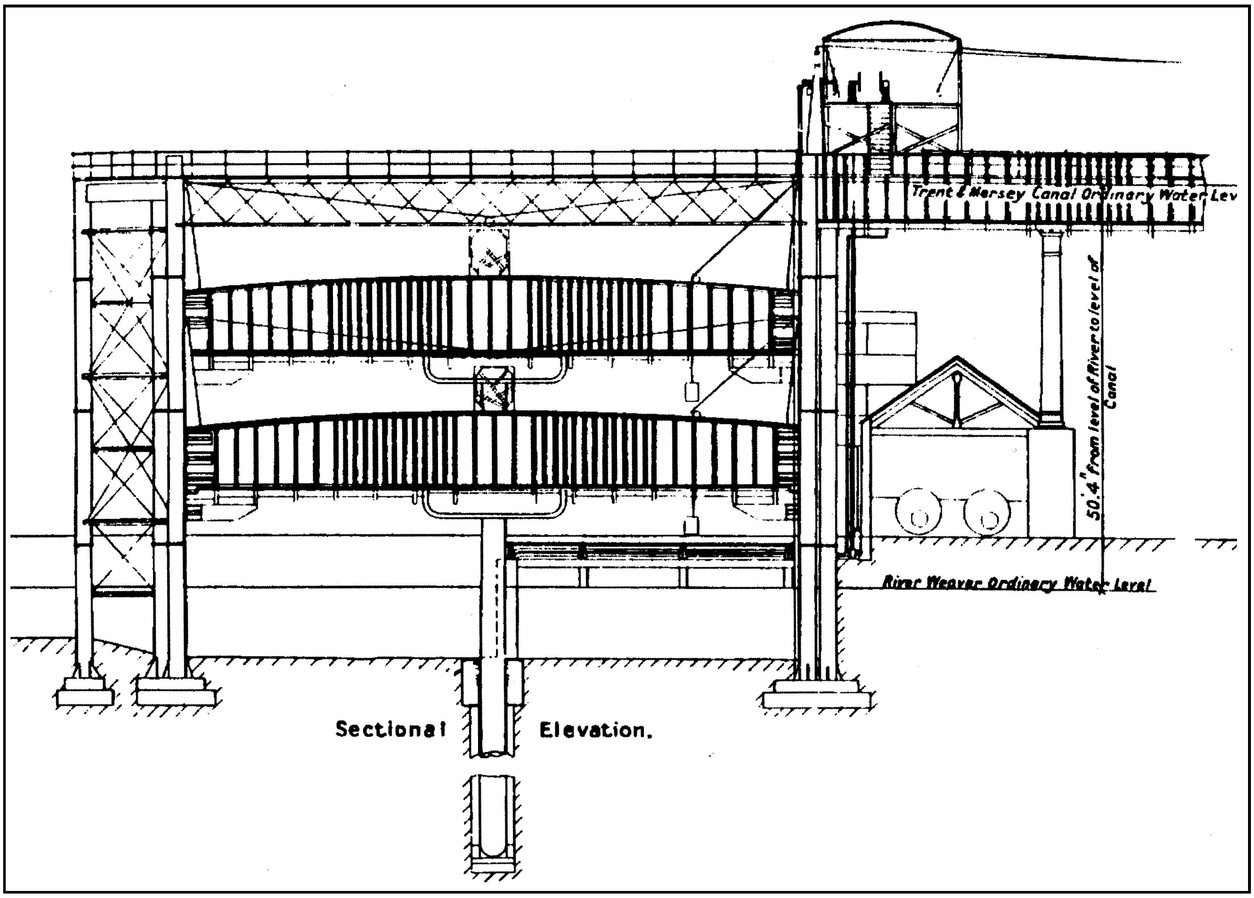


Fig. 6 Side Elevation of the Anderton Hydraulic Lift 1875[17]

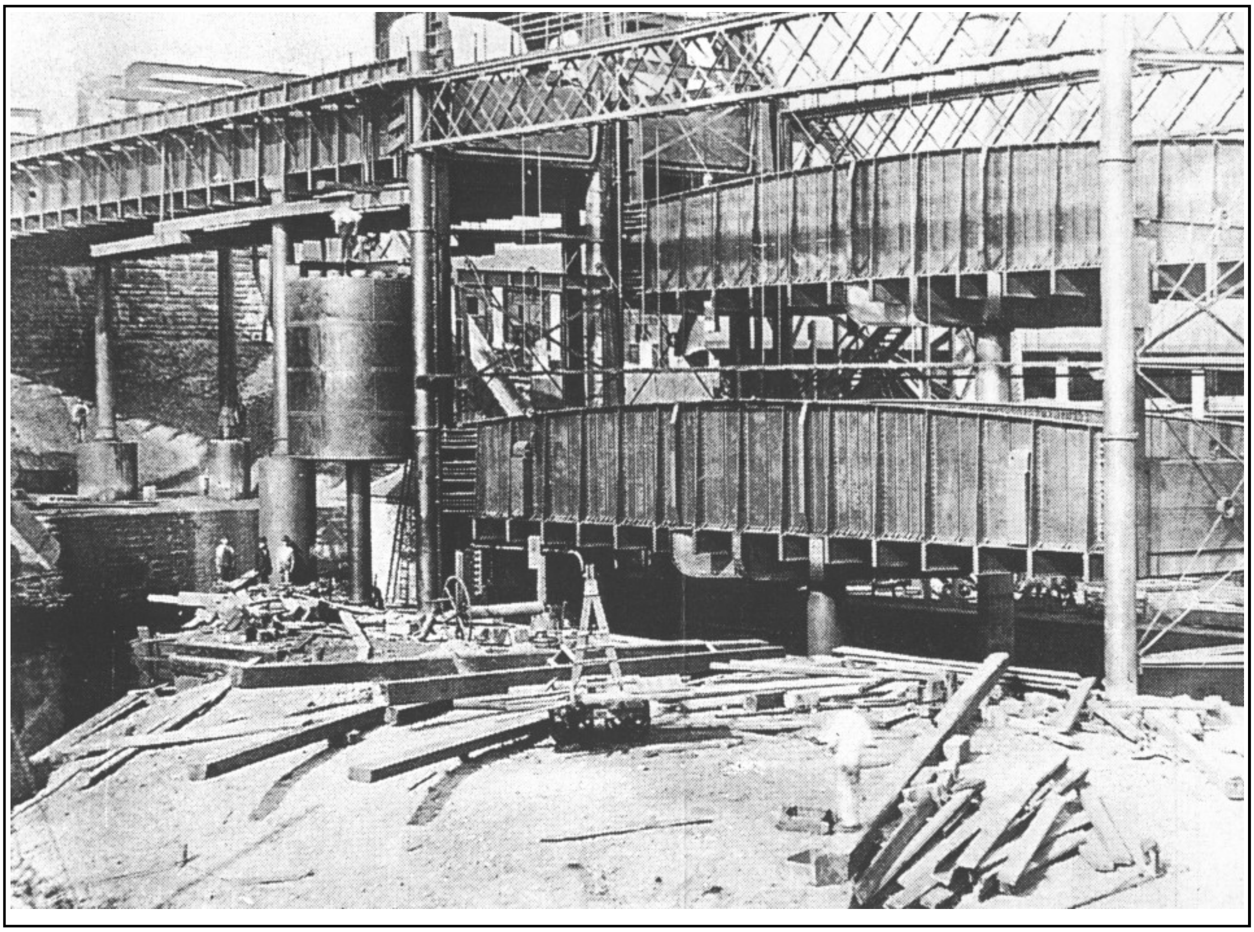


Fig. 7 Anderton Hydraulic Lift under construction[20]
Note the rams, the caissons, and the accumulator

congestion[21]. The lift proposed was to be larger than the Anderton lift in order to accommodate 300-ton boats. Construction began in 1875, was delayed somewhat by the main St.Omer-Bordeaux railway that rattled across the chosen site, and by the difficulty of establishing sound foundations in poor soil (terrain détestable), but was completed in 1888, the lift being opened on 20 April 1888. Apart from being much bigger, the Les Fontinettes lift was superior to Anderton in three important respects; the presses and rams were coated with copper to avoid the corrosion that was slowly ruining the Anderton lift; the sumps were drained and pumped dry; and the steam engine at Anderton had been replaced by a water turbine.

The Les Fontinettes lift worked well, survived two world wars, and was finally closed in the 1950s when the standard boat in Europe had become a much larger 1350 ton "European" boat which the caissons could not accommodate. The lift was retained as a monument, with boats in both the caissons, one up, one down, as if ready to operate tomorrow, with guided tours every Sunday at 4pm. It has been replaced by a single deep lock with a vertical single blade lower gate.

Hydraulic Lifts - Canal du Centre, Belgium

Simultaneous with the building of the Les Fontinettes lift, the Belgians began building the Canal du Centre, to join the Brussels-Charleroi Canal with the Mons-Conde Canal, providing an outlet for coal from the Meuse Basin to West Belgium and Northern France.[21] This canal was to include four hydraulic lifts, with a total lift of 66 metres. The lifts were similar to the Les Fontinettes lift, with slightly larger caissons able to take 400-ton boats. The first lift was completed in 1888 and was opened by King Leopold with brass bands playing and great ceremony.

The lifts are all still in use, using the original hydraulic equipment. Lifts one and four have their own salles des machines, but lifts two and three, which are only half a kilometre apart, share a salle des machines which takes water from above lift two and discharges it below lift three, giving it a three atmosphere useable pressure.

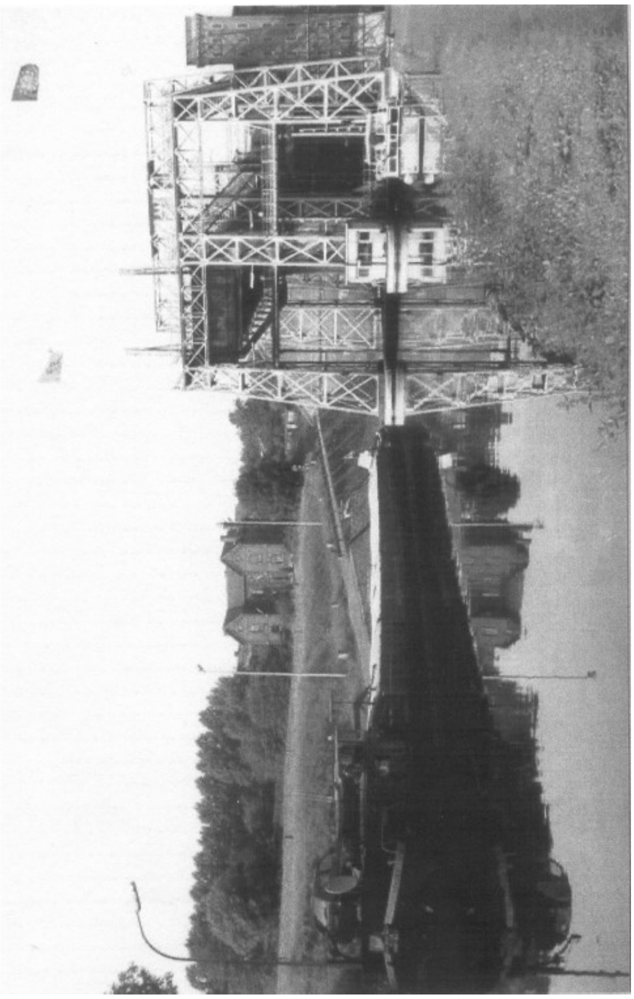
Hydraulic Lifts - Ontario, Canada

Two hydraulic lifts were built in Canada on the Trent canal, at Peterborough and Kirkgate between 1895 and 1907.[22] They were similar to the Belgian lifts, with wider caissons. The Peterbough lift is still in use today. They were the last hydraulic lifts built.

Henrichenburg Float Lift[23]

The Dortmund arm of the Dortmund-Ems canal

Fig. 8 Hydraulic Lift, Les Fontinettes, France, 1999. Note the boats in both caissons



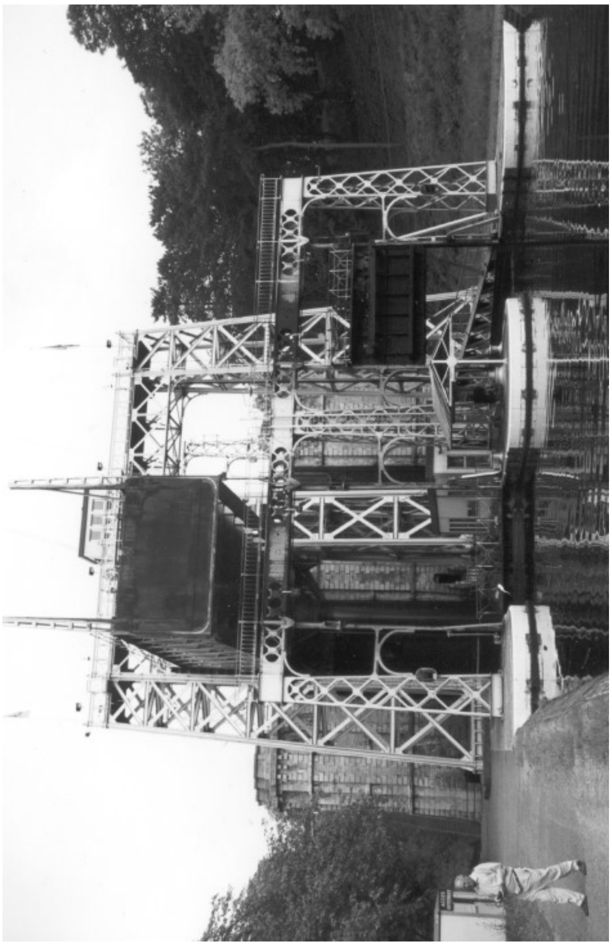


Fig. 9 (above left) Boat entering La Louvriere Lift, Belgium, 2000
Note the car on the deck of the boat

Fig. 10 (left) Lift No.2 at Houdeng, Belgium, 2000
BIAS member Dave Feltham in foreground. It worked well, but had little to do until the canal and the other three lifts were completed. Completion was planned for 1915, but was delayed by the First World War, finally taking place in 1917

Fig. 11 (above) Salles des Machines at Braqueginies, Belgium, 1999
Note the towers for the accumulators

is at summit level and all its water is pumped. It is 14 metres higher than the main arm of the canal. To avoid the vast loss of pumped water that a conventional lock would entail it was decided to build a lift. Instead of following the current fashion and building an hydraulic lift the canal authorities built a lift with a single caisson able to accommodate 800 ton boats supported on 5 floats in a manner similar to the Rowland & Pickering lift at Ruabon a century earlier. It was raised and lowered by screws in nuts at the corners of the caisson, the screws rotated by gears and an electric motor. The lift was built between 1894 and 1899. It worked well, without breakdown, until 1962 when it was replaced by a larger similar lift able to lift European boats.

Fig. 12 Strepy Lift nearing completion, 1999.
A giant lift is under construction at Strepy to replace all four hydraulic lifts and take European boats. Work began in 1974 and was nearing completion in the summer of 2000. It should be presumed that the Belgian hydraulic lifts will be dismantled in the next ten years.

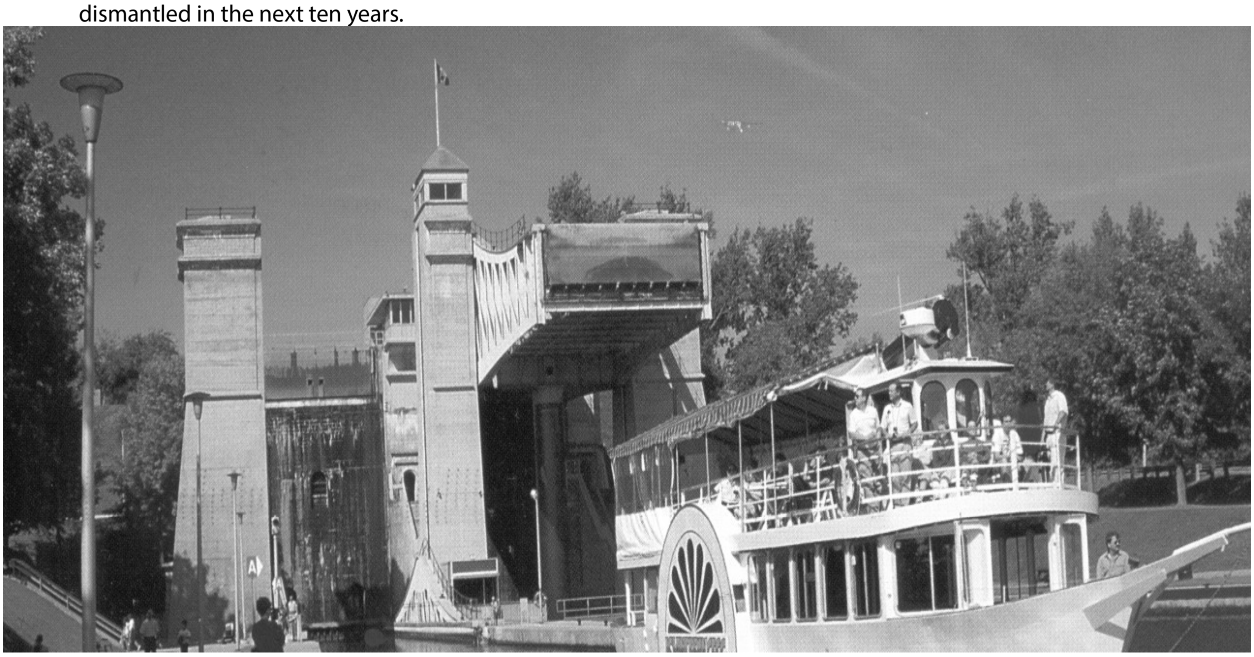


Fig. 13 Postcard of Peterborough Lift; photo by L.K. Mowry

Fig.14 Boat entering caisson at lower level, Henrichenberg Float Lift

Anderton rebuilt 1908[24]

The Anderton hydraulic lift had a short life. Corrosion of the cast iron rams made it difficult to get a good seal at the glands; the steam engine wore out and was replaced by an electric motor in 1902. In 1904 the pressure pipes began to fail. In 1908 the lift was rebuilt as a mechanical lift, using the original caissons, but with the sumps drained and pumped dry, and the caissons balanced by counterweights and raised and lowered by wire ropes and pulleys, powered by electric motors. A massive steel frame was built to support the lifting machinery, which was now overhead rather than beneath the rams. In this form the Anderton lift functioned until 1983, when the annual inspection and painting revealed serious corrosion in the supporting ironwork and the lift was closed and dismantled.

In February 2001, rebuilding was underway, funded by the National Lottery and voluntary contributions, and it is hoped to reopen the lift late in 2001.

Twentieth Century Lifts[26]

In the last century the Henrichenburg float lift and the Anderton mechanical lift were the models of all the lifts subsequently built, most of them in Germany. At Niederfinow, near Berlin, a cable and pulley lift was opened in 1934 capable of lifting 1000-ton boats. At Rothensee, near Magdeburg, a float lift was opened in 1939, again able to lift 1000-ton boats. . At Henrichenburg the 1899 float lift was replaced in 1962 by a larger float lift capable of raising 1350-ton European boats. At Scharnbeck, near Luenburg, a cable and pulley lift was built in 1977, with two caissons each long enough to accommodate push tow pairs and with a lift of 38 metres. And

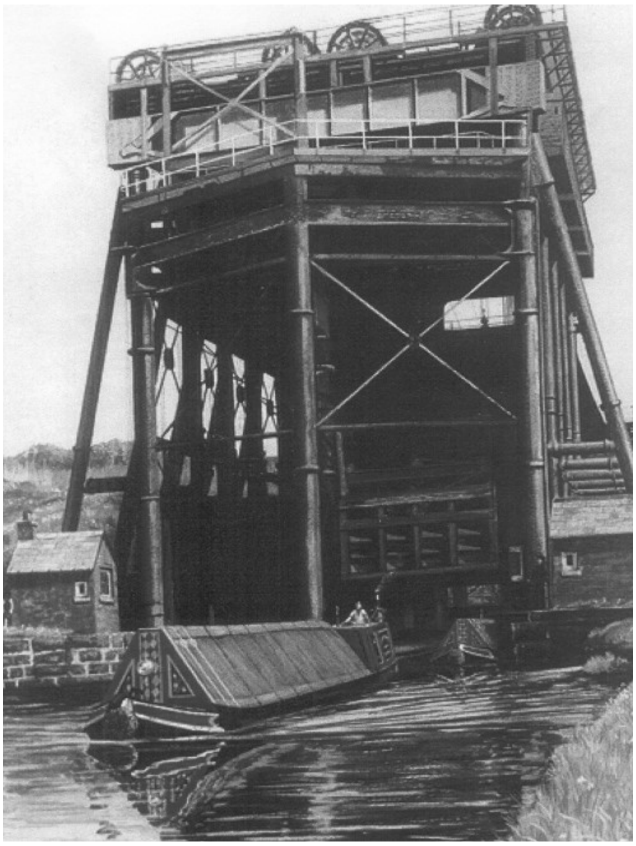


Fig. 15 Post Card of Anderton Lift in rebuilt form. Note the massive frame to bear the weight, and pulleys on top

in Belgium, as already mentioned, a huge cable and pulley lift has been under construction since 1974 to replace the four magnificent hydraulic lifts; when complete it will lift 1350-ton boats 73 metres. In the summer of 2000 it appeared to be near completion, with work proceeding on the aqueducts and channels to join it to the upper canal level.

Twenty First Century Lifts[27]

In two hundred years one would expect every possible form of canal lift to have been built. Yet in the summer of 2000 construction began of a novel form of canal lift at Falkirk, Scotland. Named the Falkirk Wheel, and ominously claiming to be part engineering part sculpture, this lift is intended to replace the locks at Falkirk that were destroyed when a motorway was built across the canal route between Glasgow and Edinburgh that was closed in the 1960s. Completion is planned for the summer of 2001, when it will be seen exactly how it works.

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Appendix

CANAL	LOCATION	DATES	CAISSON SUPPORT	MOVED BY	MAX BOAT SIZE
Somerset Coal	Combe Hay	1792-1799	Water Immersion	Boy, rollers & chains	70' x 7'
Ellesmere	Ruabon	1794-1796	Float	Man, rollers & chains	70' x 7'
Worcs & B'ham	Tardebigge	1810	Chains & c'terweights	2 stout men	70' x 7'
Dorset & Somerset	Mells	1798-1800	Balance lift 2 chains	Imbalance, gravity	26'x6'x2'3"
Grand Western 7	Nynehead	1830-1867	Balance lift, 3 chains	Imbalance, gravity	26'x6'6"x2'3"
Trent & Mersey	Anderton 1	1875-1908	Balance lift, hydraulic	Imbalance, gravity	75'x15'6"
Neufosse, France	Fontinettes	1888-1955	Balance lift, hydraulic	Imbalance, gravity	127'x16'x7'
Centre, Belgium 4	Houdeng	1888-	Balance lift, hydraulic	Imbalance, gravity	141'x19x8'
Trent, Canada 2	Peterboro'	1907-	Balance lift, hydraulic	Imbalance, gravity	140'x33'x8'
Dortmund-Ems	Henrichenburg	1899-1962	5 floats	4 screws, electricity	223'x28'x8'
Trent & Mersey	Anderton 2	1908-1983	Cables pulleys & c'wts	Gears, electricity	75'x15'6
Mittelland	Niederfinow	1934-	Cables pulleys & c'wts	Gears, electricity	278'x39'x8'
Elbe Lateral	Scharnbeck	1977-	Cables pulleys & c'wts	Gears, electricity	328'x39'x11'
Mittelland	Rothensee	1939-	2 floats	Nuts, guides, electricity	279'x39'x8'
Dortmund-Ems	Henrichenburg	1962-	2 floats	Nuts, guides, electricity	295'x39'x10'
Centre, Belgium	Strepy	building	Cables pulleys & c'wts	Gears, electricity	299'x39'x10'
Forth Clyde	Falkirk	building	Wheel & gondolas	Gears, electricity	