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LUGGIE AQUEDUCT, KIRKINTILLOCH on the FORTH and CLYDE CANAL

An historical engineering assessment

by

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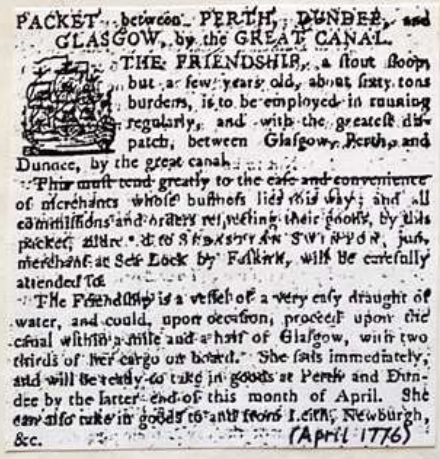
GENERAL

The 35-mile Forth & Clyde or 'Great' Canal was Britain's first major ship canal. When completed in 1790, it enabled full-masted ocean-going ships to cross Scotland between the North and Irish Seas via a 16-mile, 156ft high summit level extending from near Castlecary via Kirkintilloch to Glasgow at Stockingfield, west of Maryhill. The creation of this remarkable facility offered ship-owners an alternative to carrying their cargoes around Scotland's hazardous coast by the aptly-named Cape Wrath and it soon attracted use. This was not however its first use as the canal had been partially operational for nearly 17 years.

Under the superintendence of Britain's leading civil engineer, John Smeaton (1724-92) FRS, construction of the canal commenced in the east at the River Forth in 1768 with a sea-lock which formed the nucleus of the town of Grangemouth and slowly climbed through 19 more locks to the summit level. In September 1773 the navigation was opened at a width of 56ft and a depth of 7ft to Kilsyth and Kirkintilloch, east of Luggie Aqueduct which was then under construction. Smeaton then resigned, and Robert Mackell (d.1779) who was the Resident Engineer, completed the canal to Stockingfield in November 1775 and to Hamilton Hill on the Glasgow Branch at the 'Old Basin' near the present British Waterways Board Offices, by November 1777. As each section became navigable, usage increased, particularly between Glasgow and the Scottish east coast ports. (Fig.1)

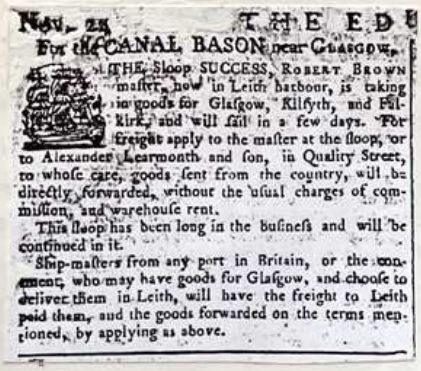


PACKET between PERTH, DUNDEE, and GLASGOW, by the GREAT CANAL.

THE FRIENDSHIP, a stout sloop, but a few years old, about sixty tons burden, is to be employed in running regularly, and with the greatest dispatch, between Glasgow, Perth, and Dundee, by the great canal.

This must tend greatly to the ease and convenience of merchants whose business lies this way; and all commissions and orders respecting their goods, by this packet, addressed to SEBASTIAN SWINTON, jun. merchant at Set-Lock by Falkirk, will be carefully attended to.

The Friendship is a vessel of a very easy draught of water, and could, upon occasion, proceed upon the canal within a mile and a half of Glasgow, with two thirds of her cargo on board. She sails immediately, and will be ready to take in goods at Perth and Dundee by the latter end of this month of April. She can also take in goods to and from Leith, Newburgh, &c. (April 1776)



Nov. 25. THE EDINBURGH

For the CANAL BASON near Glasgow,

THE Sloop SUCCESS, ROBERT BROWN master, now in Leith harbour, is taking in goods for Glasgow, Kilsyth, and Falkirk, and will sail in a few days. For freight apply to the master at the sloop, or to Alexander Learmonth and son, in Quality Street, to whose care, goods sent from the country, will be directly forwarded, without the usual charges of commission, and warehouse rent.

This sloop has been long in the business and will be continued in it.

Ship-masters from any port in Britain, or the continent, who may have goods for Glasgow, and choose to deliver them in Leith, will have the freight to Leith paid them, and the goods forwarded on the terms mentioned, by applying as above.

Fig.1. Freight advertisements in the Edinburgh Advertiser 1776-8.

GENERAL contd)

The work proved more difficult and costly to execute than had been envisaged at the outset and the effort to reach Glasgow exhausted the funds for the entire project and there were doubts about it ever being completed. However, after a 7-year standstill, the venture obtained a new lease of life using Forfeited Estates funding and was completed to the River Clyde from 1785-90 via 19 locks and Kelvin Aqueduct under the able superintendence of the notable canal engineer, Robert Whitworth (1734-99). The effect of this incremental construction and an indication of the early growth in usage of the navigation can be seen from Table 1.[1]

YEAR	REVENUE (£sd)	OPENED FROM THE RIVER FORTH TO:
1774	678 15 7¾	Kirkintilloch (9/73)
1775	1148 18 9¼	
1776	2051 6 5½	Glasgow at Stockingfield (11/75)
1777	4092 14 6¾	
1778	510 17 0	Glasgow at Hamilton Hill (11/77)
1786	5781 18 5½	
1789	6986 7 11	
1791	12336 17 7	Clyde (7/90), Monkland Canal (12/90)
1800	21607 6 8	
1815	46974 16 10	

Table 1 Annual Revenue of Forth & Clyde Navigation 1774-1815

The canal was Scotland's first major civil engineering project, which, largely because of its unprecedented nature and the initial inexperience of much of the work-force and local management, took 15 years to build. The work was labour intensive, at times employing more than 1000 men, and had the long-term benefit of developing skills which made a significant contribution to the basic infrastructure of Scotland during the Industrial Revolution. The navigation reached a peak carriage of 3 million tons in 1866, which thereafter declined as freight was increasingly carried on the railways. From 1774, based on the saving of sea miles and the advantage that on a canal a horse could pull 100 times more than on a road, the navigation enabled cargoes, particularly minerals, manufactures, timber and agricultural produce to be carried much more economically than previously. This had beneficial effects across the economy and thus the venture, in addition to profiting its owners, made a significant contribution to the well-being of the nation. The canal's very existence became, and still is in terms of the environment, an integral part of the every day life of the communities through which it passes.

For a canal project of this size and complexity, second only in the

GENERAL contd)

western world to the Languedoc Canal connecting the Mediterranean and the Atlantic Ocean across France a century earlier, the Canal Company had to look for an engineer with outstanding ability. They were fortunate in obtaining the services of Smeaton, who had successfully completed the fourth Eddystone Lighthouse and was at the head of his newly emerging profession. Smeaton outlined his grand design for the canal with estimated costs in reports of 1764 and 1767, with the judicious caveat that 'there must be a degree of latitude in an affair of such consequence for second thoughts and improvements'.[2,3] He became Engineer-in-Chief to the Company in April 1768 and at the same time Mackell was appointed 'Sub' or 'Resident' Engineer, which is believed to have occasioned the first use of this now everyday title. Their annual salaries were £500 and £315 respectively. Smeaton conducted the strategic operations, major decision-making and design and plan preparation from his home at Austhorpe in Yorkshire and during occasional visits to Scotland. Mackell was responsible for the everyday management of the project, including the placing of contracts and setting out and, in fact, exercised considerable autonomy regarding the 'as built' line, level and structural detail of the canal. An example of the extent of this autonomy can be gleaned from a comparison of the copy drawings of Luggie Aqueduct in this assessment with the structure as built.

Not much is known about Mackell, he may have been a Glasgow millwright in 1742. In 1767 he was practising as an engineer and constructed a horse-powered pump for Port Glasgow dry dock to Smeaton's design. In the same year he was also associated with the then little known James Watt (1736-1819) in advocating a shallow, narrow-boat, canal between Glasgow and Carron Ironworks. This proposal was overtaken by Smeaton's more ambitious scheme. On Forth & Clyde Canal work, although Mackell seems to have had his limitations in dealing with the paper-work of the project, he was essentially effective in getting the work done, but at a cost, and retained his Engineer-in-Chief's support. In August 1772 a sub-committee recommended Mackell's dismissal for incompetence, but Smeaton advised that this would be detrimental to the Company's interest. Two years earlier Smeaton had commended Mackell's 'judgement and attention to the interest of the Company' and found the works 'in the general and in the things most material, exceedingly well executed and to my satisfaction...Mr. Mackell has now the weight of the whole affair

GENERAL (contd)

upon his hands'.[4] Smeaton sought to withdraw from the venture at this stage because of the pressure of other commitments but the Company would not hear of it. In fact, it was not until September 1773, when the navigation was opened to Kirkintilloch and its extension to Glasgow ensured, that Smeaton was able to resign his post by mutual agreement. In the context of Luggie Aqueduct, which was not designed until 1772, it is fortunate that he did continue in post.

The construction of the canal was carried out by local labour under scores of contracts. One of the major contractors was William Gibb (1736-91) and John Moir, stonemasons of Falkirk, of whom Gibb seems to have been the senior partner. Their work included construction of the Luggie and Kelvin Aqueducts. The Gibb family developed into Scotland's leading firm of contractors for harbour, river improvement and bridge works and their civil engineering association continues today in the eminent firm of consulting engineers, Sir Alexander Gibb and Partners.[4]

CROSSING THE LUGGIE

1764-68(Nov) The line originally suggested for the canal at Kirkintilloch was to the north of the Glasgow to Stirling road at or near the level of the River Luggie and using its water to supply the canal. The canal was envisaged as crossing the river through the mill-pond some 400-500m north of where the aqueduct now stands. Smeaton allowed £300 for extra work.[2,3] (Fig.2)

c.1770-71 The more or less present line and level of the canal were determined, almost certainly, by Mackell.

1772(Spring) Smeaton prepared and sent to the Company three drawings for Luggie Aqueduct. (Figs.3-5)

1772(May) Gibb was authorised 'in the interim' to 'quarry and hew the stones for Parkburn (aqueduct about ½ a mile west of the Luggie) and drive the stones for that and Luggie Bridge...'.[5] (The quarry, presumably local, is not named)

1772(Jun 16) The Company resolved 'to proceed in building Luggie Bridge agreeable to Mr. Smeaton's directions and order Mr. Mackell to get further estimates and expense of the severall parts and also of the total expense in one view from Wm. Gibb or any other tradesman'.[5]

1772(Aug) Following a favourable report from Smeaton who was then

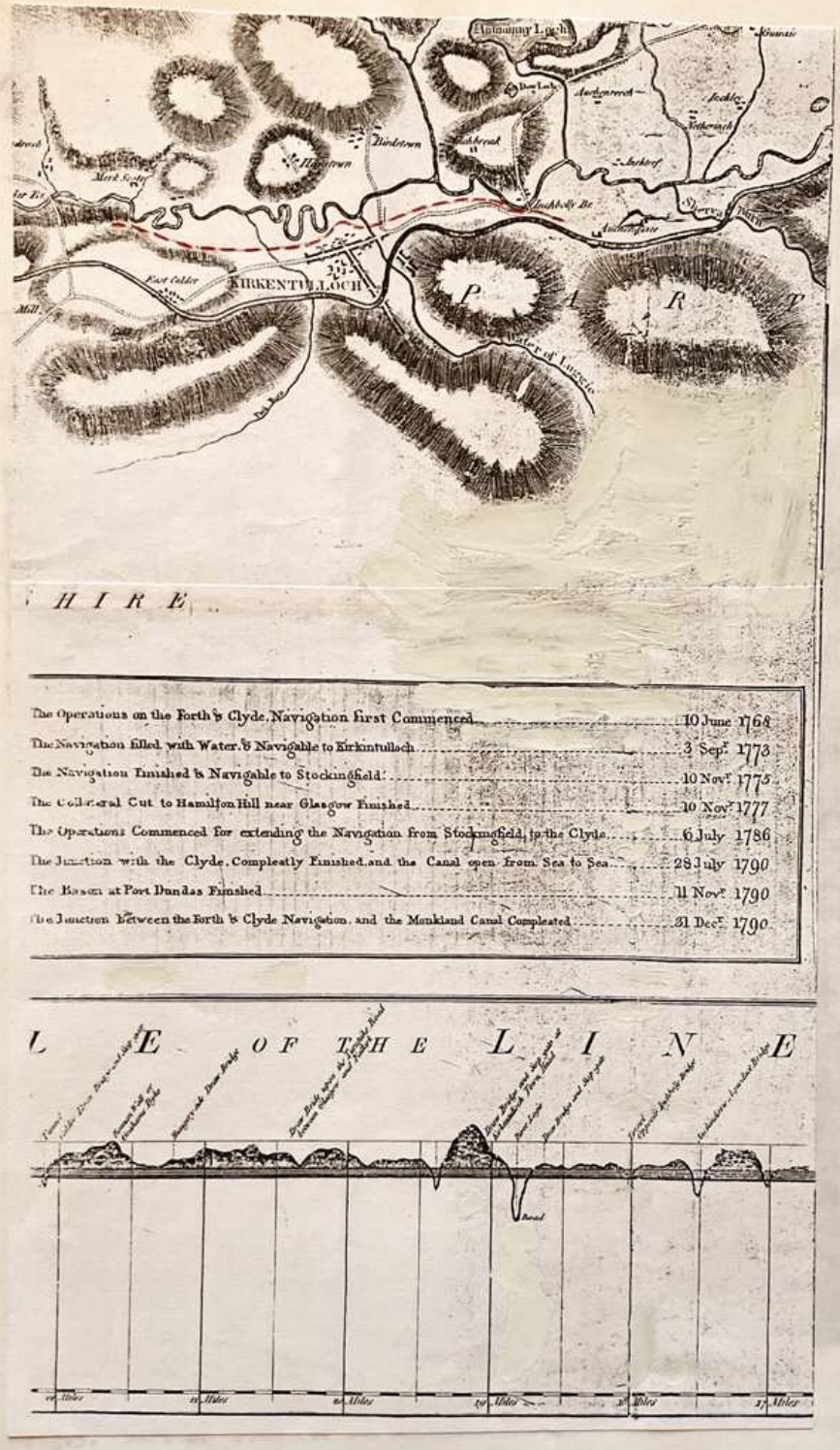


Fig.2. Part of Plan and Longitudinal Profile of Forth & Clyde Canal at Kirkintilloch, 1790. Original proposed line in red. The section shows a road passing under the canal with the Luggie, but the plan does not. 6

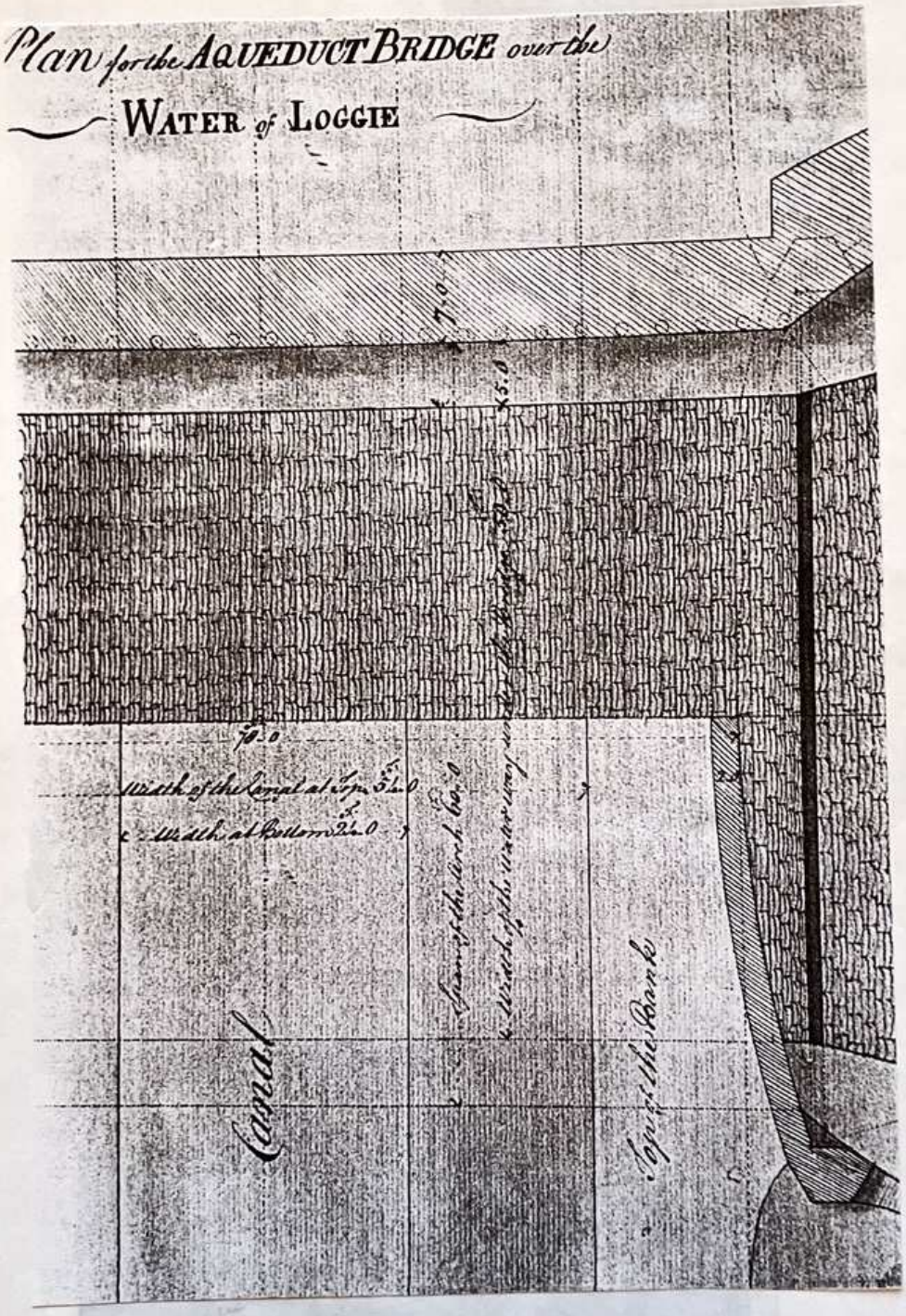


Fig.3. Part of 'Plan for the Aqueduct Bridge over the Water of Loggie'[7]

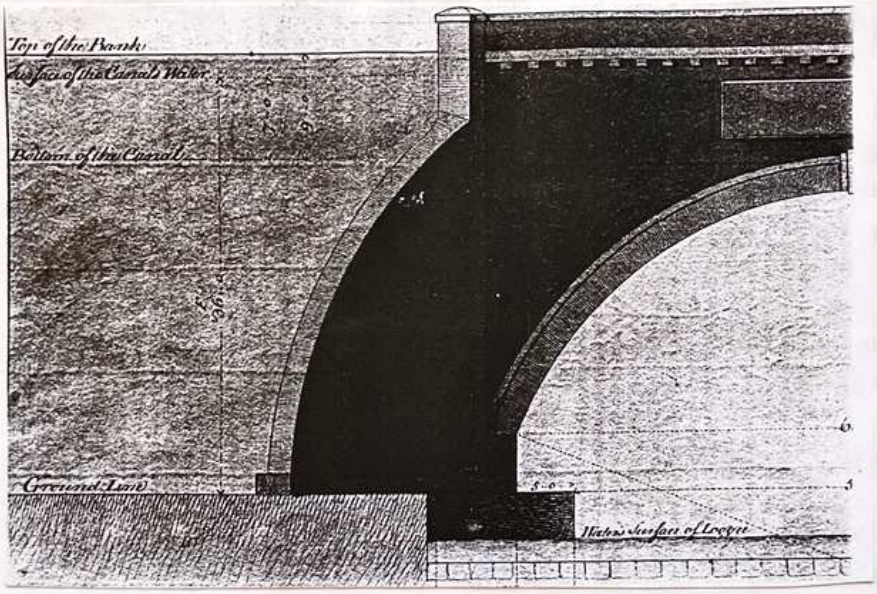


Fig.4. Part of 'Elevation of an Aqueduct Bridge...'[8]

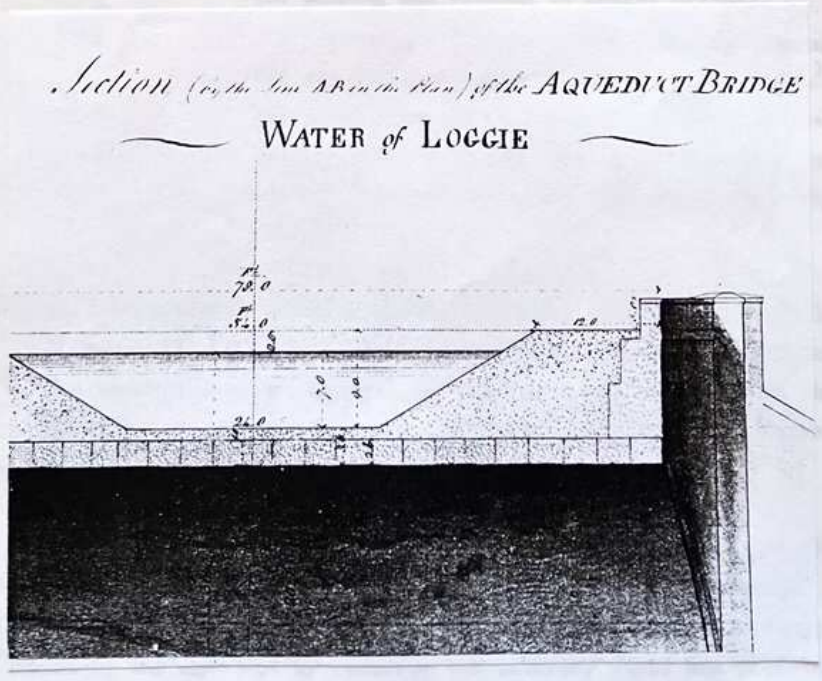


Fig.5. Part of 'Section...of the Aqueduct Bridge...'[9]

CROSSING THE LUGGIE contd)

1772(Aug 5)	in Scotland, on Gibb's proposal, Mackell was authorised to enter into a contract with him for building the aqueduct.[5]
1773(Jan)	Mackell was authorised to enter into a bargain with Gibb for banking Luggie Bridge at 8d per cubic yard.
1773(Mar)	Two proprietors George Clerk and George Inglis when inspecting the work with Mackell, 'found the aqueduct carrying on with expedition and the banking and cutting through the height at Kirkintilloch and observed to the engineer that great care ought to be taken in puddling (the lining to the canal?) on this bank.'[5]
1773(Sept 3)	The navigation opened to Kirkintilloch, east of the aqueduct.
c.1774	Aqueduct completed (date and cost not yet found)
1775(May)	Gibb claimed that 'he had done a great deal of work for which there was no contract and never knew what he was to get for these articles and craved time to make another tryall of the mensuration of part of the banking and cutting at Luggie Bridge.'[10]
1845	The Edinburgh & Glasgow Railway Company obtained an Act for Branch Lines to Campsie and Kilsyth.[11]
1858	The Campsie Branch was opened in 1858 with the railway passing through the aqueduct arch on a masonry twin-culvert about 10ft above the river. (Fig.9).[12]

COMMENT

As Scotland's first major aqueduct and the prototype for Kelvin Aqueduct (1786-9), and also, because of the practice it displays of the eminent Smeaton, Mackell and Gibb in a project of great national significance, this remarkable structure easily earns its Class A historic buildings listing.

It is noteworthy that the canal overpasses the Luggie at its typical full construction width of 56ft, as befits a major ship canal designed in the grand manner. The temptation to reduce the capital cost of the aqueduct by reducing the waterway width was resisted, presumably being outweighed by the user-convenience of uninterrupted 2-way passage on the long summit level. The time-saving benefits to

COMMENT contd) users must have justified the extra capital cost many times over.

Another fascinating design aspect of the aqueduct is that it has masonry arches in two planes. In addition to the conventional vertical segmental arch, it has on each side a horizontal segmental arch, with a versine of about 1/10th span, thrusting off the abutment wing-walls. (Fig.3) Because of the considerable quantity of earth and clay fill, the horizontal arches represent an elegant, prudent and, as time has shown, successful 'state of the art' measure.

The main departures from the drawings in the as built structure, probably initiated by Mackell with the presumption of Smeaton's agreement, were, that the aqueduct was built with a span of 50ft and not 60ft, and that cast iron railings were substituted for ashlar masonry in the parapets. These and other minor differences, such as in the height of the key-stone, can been seen from a comparison of Figs 4 & 6. These railings help to reduce the appearance of heaviness above the extrados of the arch when the structure is viewed in elevation. The railings represent a fine, early, example of the iron-founders art and are probably contemporary. In view of both Mackell and Gibb's connections with Falkirk, it seems quite credible that they were made at Carron Ironworks and transported to site along the canal c.1774. The increase in canal depth from 7ft to 8ft in 1788 is unlikely to have affected the tow-path level at the parapets. (Figs 5,7 & 8)

In building technique terms, the 90ft overall width of the aqueduct would have required a considerable cost outlay for conventional centering to support the formation of the arch rings. Considerable ingenuity in reducing this cost was shown, probably by Mackell or Gibb, in devising a centre 30ft broad, which ran on small rollers, and was moved across the width of the structure in three lengths. This mode of operation, which is believed to have been unprecedented on this scale in Britain, was so skilfully done that the two joinings are scarcely discernable.

The railway expedient undoubtedly detracts from Smeaton's design but, nevertheless, now forms a curious and integral part of the history of the site. (Figs 9 & 10)

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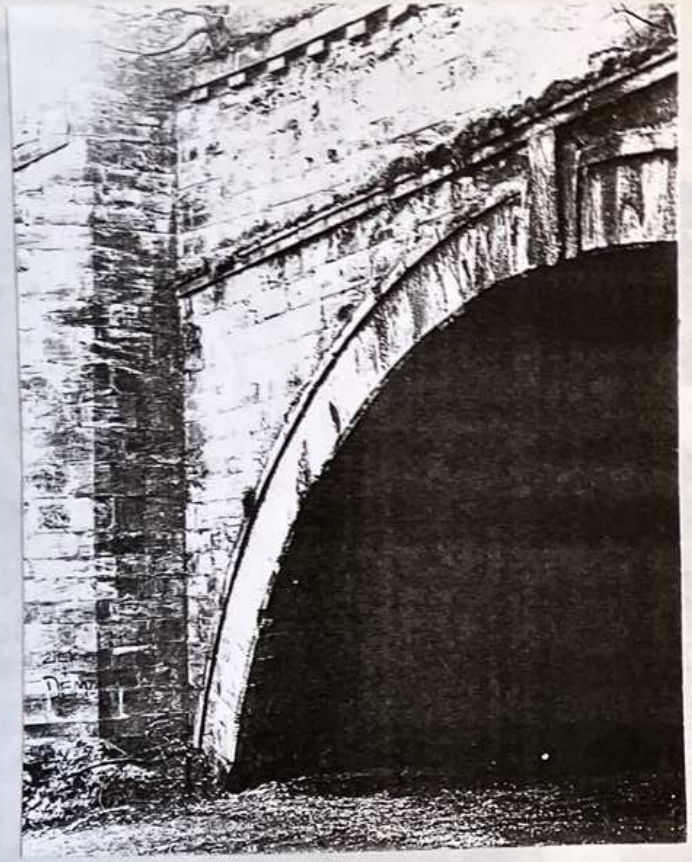

Fig.6. Luggie Aqueduct -half span.

Fig.7. Luggie Aqueduct Railing.

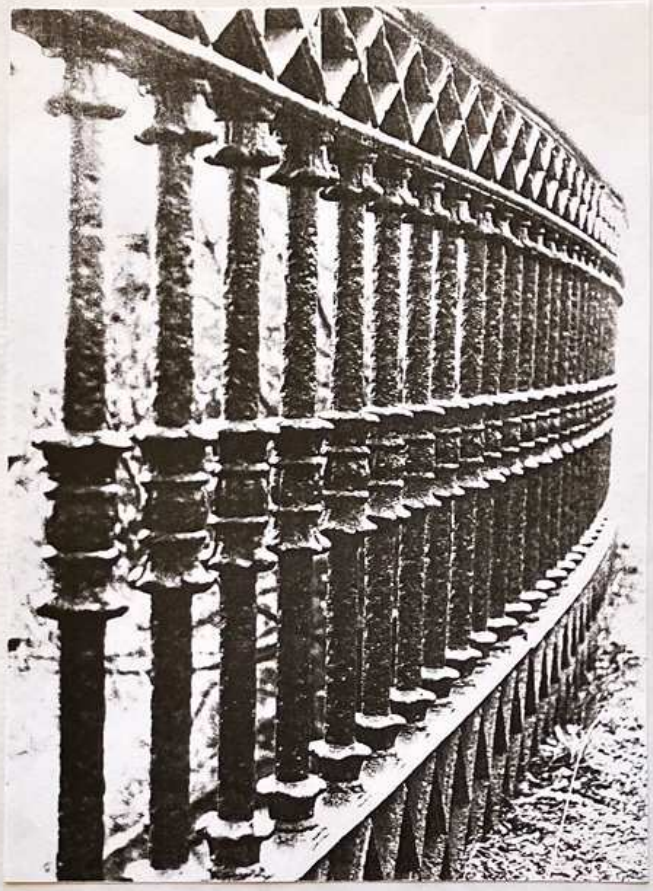

Fig.8 Luggie Aqueduct Railing showing horizontal curvature.

Fig.9 Luggie Aqueduct and twin-span railway culvert.

Fig 10. Luggie Aqueduct today - showing railing above former railway twin culvert entrance at right.