

# Technology, Economics, and Canal Development: an early technical book and what it reveals

Mike Clarke

*including a translation by Mike Clarke of*

## Instructions for the Design and Implementation of Navigable Canals

by

Sebastian von Maillard

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Railway & Canal Historical Society

2021

Maillard's book first published in German 1817  
This Translation and Introductions published 2021  
by the Railway & Canal Historical Society

[www.rchs.org.uk](http://www.rchs.org.uk)

The Railway & Canal Historical Society was founded in 1954  
and incorporated in 1967.

It is a company (no.922300) limited by guarantee  
and registered in England as a charity (no.256047)

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ISBN 978-0-901461-71-1

Layout by Mike Clarke

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# Technical Training: Education and the Craftsman

Comparing this book by Maillard with other contemporary English, German and French language technical books, does highlight the difference in technical education of the period between Britain and the rest of Europe. In 1817, Maillard was beginning to develop theoretical formulae for such things as stresses on lock gates and on soil mechanics, showing that mathematically, continental engineers were at least two decades in advance of those in England. It would be difficult to catch up, and one author has suggested that this would be virtually impossible because of English society's low regard for all levels of industrial workers from the mid-19<sup>th</sup> century.<sup>1</sup>

Although English craftsmen engineers had a high level of competency, their knowledge was less mathematically based and more empirical. There were centres where some form of training does seem to have been undertaken, for example the number of surveyors associated with Thomas Steers in Liverpool in the first half of the 18<sup>th</sup> century. His best known pupil was Henry Berry, who took over from him as Liverpool's Dock Engineer, and later built the Sankey Navigation. Steers also trained other surveyors, such as John Eyes, and probably Richard Melling, P P Burdett and R Beck, who set out the alternative lines for the Leeds & Liverpool Canal in Lancashire in 1768 and 1769.

There were also a group of canal engineers who came from the Halifax area, possibly as a result of Smeaton's influence. Robert Whitworth is the best known, as he became Brindley's right-hand man after meeting Brindley when he was working on the Calder & Hebble Navigation in 1765. Whitworth, who was later to be the Leeds & Liverpool Canal's engineer from 1790 till his death in 1799, was already established as a surveyor in the Halifax area by 1765, when he was 31 years old. He would have known other local men with similar skills as also based around Halifax at the time, such as the Crosley brothers, with William and his son heavily involved with Rennie on the Rochdale Canal.

John Longbothom, who first drew up the scheme for the Leeds & Liverpool Canal in 1766 was another engineer from Halifax reputed to have been trained by John Smeaton, whilst the Leeds & Liverpool's manager, Joseph Priestley from Bradford, would almost certainly have known of most of these men. A practical engineering knowledge was required by him during the 1780s when the canal had no official engineer. He must have had experience, as in 1773, both Longbothom and Priestley joined the Society of Civil Engineers,<sup>2</sup> which was formed in 1771 and renamed as the Smeatonians after Smeaton's death. Some of the country's foremost civil engineers were members, and met regularly in London when canal bills were passing through Parliament. Whitworth was a founder member, and the Priestley and Whitworth families were further linked when Joseph Priestley junior, later manager of the Aire & Calder Navigation, married Robert's daughter, Sarah, at Burnley in 1800.

In England, technical schooling was limited to simple 'school' mathematics, with further training on the job. In Scotland, education was more advanced. John Rennie began working for millwright

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<sup>1</sup> Wiener, Martin J, *English Culture and the Decline of the Industrial Spirit, 1850-1980*, ISBN 978-0-521-60479-6.

<sup>2</sup> Watson, Garth, *The Smeatonians*, 1989, ISBN 0727715267

Andrew Meikle at the age of 12 after attending a parish school. Two years later, he returned to school for two years, leaving to set up his own millwrighting business. From 1780-83, he attended Edinburgh University, studying under Joseph Black and John Robison, then working for Boulton & Watt before setting up on his own as a professional civil engineer. His academic qualifications were unusual for engineers of the time, and it was to be many years before they became the norm. The number of Scottish craftsmen who were working as engineers at this time reflects the higher standard of education in Scotland, where a few academics did encourage the education of craftsmen.

A study of contemporary European technical publications does suggest that technical education in Europe was far in advance of that in England, though with regard to creativity things were not necessarily that simple. Those attending European technical institutions usually came from the aristocracy or from the upper classes, and they seem to have had difficulty in communicating with the craftsmen ‘on the shop floor’ who actually undertook any work.<sup>3</sup> In Britain it was, in effect, almost the exact opposite, with those in charge of design and construction being craftsmen themselves. A few, such as Smeaton and Rennie, did have an academic background, but in general those in direct control of engineering projects were craftsmen, usually with minimal academic qualifications.

The lack of practical experience available to engineers educated in French technical institutions was recognised in post-Napoleonic France by Becquey, a Councillor of State and Director of the Ponts et Chaussées, who wrote a report to the king<sup>4</sup> proposing an inland navigation system over 10,000km in length linking the whole France. In his biography of Becquey,<sup>5</sup> Beugnot notes:

*By recalling the works of Fresnel, Vicat, Navier, Dufrenoy, and Elie de Beaumont, we have shown that a noble desire to extend the field of science and technology inspired French engineers. Becquey realized, however, that they could only improve by establishing good links with English engineers, less versed in theoretical knowledge than they were, but more experienced in practice, better provided with means of execution, and more enterprising; and he endeavoured to facilitate and multiply these relationships. He commissioned several engineers to visit England to examine the whole system of public works, and entrusted to others the mission of studying narrow canals, suspension bridges, MacAdam for the construction and maintenance of roads, the uses and regulations for road transport, the construction of docks and ports, the use of hot air and coal in blast furnaces, etc.*

One of the engineers sent to England was Dutens, who was in charge of constructing the Canal du Berry. His report on his visit was published in 1819,<sup>6</sup> and he subsequently built the canal to smaller dimensions than originally envisaged, with locks 3 metres wide, slightly larger than an English narrow canal. Beugnot described the reasons for Dutens’s visit to England as follows:

*Becquey being made aware of the progress of work on the Canal du Berry and the system adopted for its construction, could not help but become fearful as to the time needed for its completion. In a letter dated November 18, 1817, to the chief engineer of the canal, he thought that with the present state of the finances, it would be impossible to complete the canal, if the project was continued as approved; but that, on the contrary, if, by changing the dimensions which were currently used*



One of the narrow locks, the Ecluse du Roches, on the Canal du Berry.

<sup>3</sup> Clarke, Mike, ‘The First Steam Locomotives on the European Mainland’, in *Early railways, a selection of papers from the first international early railways conference*; Newcomen Society, 2001, ISBN 090468508X

<sup>4</sup> Becquey, L, *Rapport au Roi sur la Navigation Intérieure de la France*, 1820

<sup>5</sup> Beugnot, Arthur Auguste, *Vie de Becquey, Ministre d’Etat*, 1852, p.272

<sup>6</sup> Dutens, J, *Mémoires sur les Travaux Publics de l’Angleterre*, 1819

for the canal, and these dimensions were reduced to those of a small canal, he hoped that, on this assumption, a company of capitalists had proposed to him made to take the concession, and that, for these reasons, he wished to be informed as to whether it was possible to apply to the Canal du Berry the system of 'small navigation', which had been employed in a manner so advantageous to commerce in England.

Dutens, who directed the work of this canal, agreed with the director-general, and asked to go to England to investigate the system of 'small navigation' employed in that country, and about which he thought that they did not fully understand. The expense of the Canal du Berry, if reduced to such dimensions, would be diminished by a third, and so only 12 millions.<sup>7</sup>

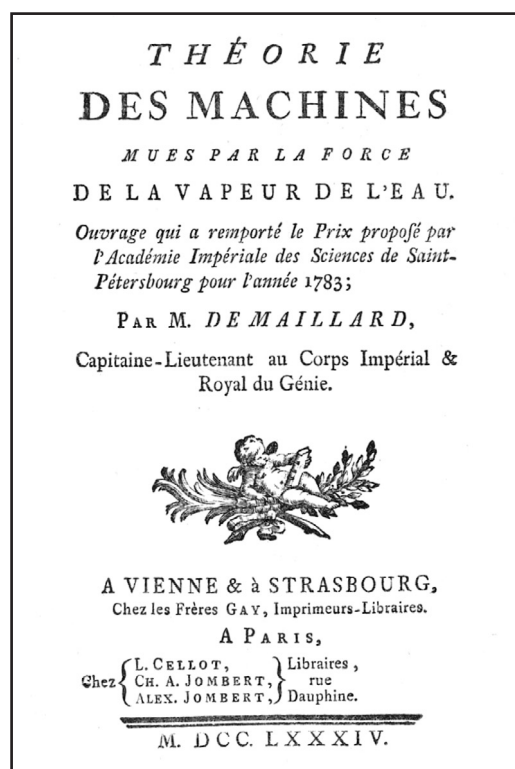
This would suggest that until Dutens had reported on his visit to England, the French only had a vague idea about the technology used on canals, and perhaps in other industries, in England.<sup>8</sup> They certainly did not appreciate the role of the craftsman in the development of industry and transport in England until after his visit.

### *Technical Publications*

Knowledge in France was 'centralised', and was organised by national institutions based in Paris, in the same way as London institutions were at the centre of much academic knowledge in England. This was one of the factors which was to cause the slow development of industry in France — and possibly in London, which was the main industrial centre of England for most of the 18<sup>th</sup> century.

18<sup>th</sup> century academic scientists were, perhaps, predominantly interested in chemistry, and there were many cases of their findings being of benefit to industry, particularly the textile printing industry. However, even there the self-trained craftsman, such as John Mercer, remained influential into the mid-19<sup>th</sup> century. There was much less interest in subjects relating to physics and the practical trades involving civil and mechanical engineering, and this slow response to the practical understanding and to the improvement of technology by English scientists and academics was compounded by their slowness in taking up modern mathematical thinking. This allowed other countries to catch up with England's lead in industrialisation, as is shown by the content of technical books published in the first half of the 19<sup>th</sup> century. Those in English were generally purely scientific, with those in French slightly more practical, but much more advanced mathematically, while German books fitted between the two, and were perhaps the most useful for those involved with manufacturing and construction. It was the slowness of English mathematicians to adopt calculus and other new mathematics which was to hold back technical education in England for decades.<sup>9</sup>

With French as his mother tongue, Maillard would have been aware of French publications, possibly more so after he entered the Engineering Corps of the Imperial Army in 1772. Through his interest in modern engineering, he seems to have maintained links with France, working with the d'Arnal brothers, Johann and Étienne,<sup>10</sup> on the



<sup>7</sup> Beugnot, Arthur Auguste, *Vie de Becquey, Ministre d'Etat*, 1852, p.201

<sup>8</sup> Harris, John, *Industrial Espionage and Technology Transfer: Britain and France in the Eighteenth Century*, 1998, ISBN 9781138418325

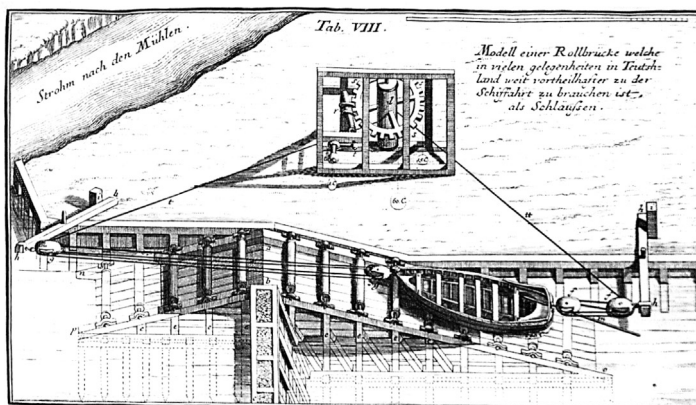
<sup>9</sup> Panteki, M, 'Wm Wallace and the Introduction of Continental Calculus to Britain', *Historica Mathematica* 14, 1987, pp119-132.

<sup>10</sup> Johann was also in the Imperial Army, while Étienne was originally a priest, giving this up to devote himself to technical research.

development of the steam engine. Maillard was awarded a prize by the Russian Academy of Sciences in St Peterburg for his paper on the subject *Mémoires sur la théorie des machines à feu* which was published in 1784. He corresponded with the German-speaking Secretary of the Academy, Leonhard Euler, whose interests were in both mechanics and mathematics. His work on differential and integral calculus form the basis of the mathematics on which engineering technology now relies.

Late 18<sup>th</sup> and early 19<sup>th</sup> century publications in German appear to be more practical than those published elsewhere, with details of specific methods to be used, whilst at the same time encompassing the new mathematics of people like Euler, and the Frenchman, Coulomb.<sup>11</sup> By the time Maillard was at work, the writings of Belidor<sup>12</sup> were beginning to be questioned, as detailed mathematical answers were being sought to overcome practical construction problems, such as soil stability.

Technical books on inland waterway engineering were increasingly published from the 17<sup>th</sup> century.<sup>13</sup> In Italy, Zonca's *Novo teatro di machine et edificii par vane et sicur operationi* appeared in 1607, followed ten years later in the Netherlands by Simon Stevin's *Niuwe maniere van Sterctebou door Spilsluysen*. Several similar books appeared during the century in Italian, Dutch and French, with Sturm publishing the German *Fang-Schleussen und Roll-Brücken* in 1720, and Polhem's *Forschlag* following in Sweden six years later.



Design for an inclined plane as illustrated in Sturm's *Fang-Schleussen und Roll-Brücken*.

It was only in 1729 that an English language work was written, Richard Cassel's *Essay on Artificial Navigation* — not only was he German, but it was published in Dublin, where, at the time, interest in inland waterways seemed to be much greater than in England, certainly at government level. The greater availability of technical publications across Europe seems to confirm that technical education on the mainland of Europe was more advanced than in England.

Much English research was published by the *Royal Society*, founded in 1660, and the *Society for the Encouragement of Arts, Manufactures and Commerce*,<sup>14</sup> founded in 1754 and based on *Dublin Society for improving Husbandry, Manufactures and other Useful Arts*, founded in 1731. However, this research tended to be academic, and only those articles on agricultural improvement and chemistry were of a more practical nature. The lack of technical research reflects the lack of technical education in England, other than that provided by the traditional craft apprenticeship. A brief survey of technical books which had been published prior to 1820<sup>15</sup> shows that there were few practical English books on hydraulic engineering. There were a number on surveying and carpentry, both subjects useful to the canal builder, but these were aimed more at those involved with land management and house construction, important for the landed gentry of southern England, but not so useful for those developing new industries and canals in the north and midlands.

Prior to Maillard and his group setting out for England in 1795, a set of notes describing the relevant books which were available in Vienna had been drawn up.<sup>16</sup> These included several standard works, such as the French translation of Frizi's work, *Traité des Rivieres et des Torrents*, and La Lande's, *Des Canaux*

<sup>11</sup> Coulomb was involved in canal engineering during his early professional career in the 1780s, when he was called in to look at the designs for canals in Brittany. See Gillmor, C Stewart, *Coulomb and the Evolution of Physics and Engineering in 18<sup>th</sup> Century France*, 1971, ISBN 0-691-08095-X, pp.51-60

<sup>12</sup> Belidor, Bernard Forest de, *Architecture Hydraulique*, 1737-1753, 4 vols.

<sup>13</sup> See Appendix 9

<sup>14</sup> Now known as The Royal Society of Arts.

<sup>15</sup> See Appendix 9

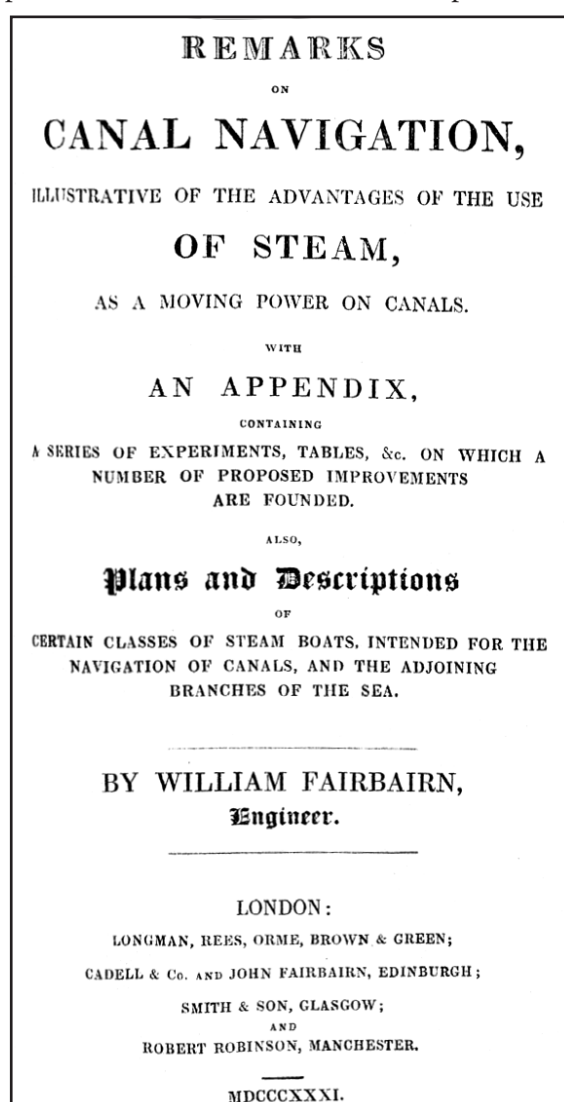
<sup>16</sup> Austrian State Archives, AT-OeStA/FHKA MBW Anhänge Kanal Akten 1, 362-372

*de Navigation*, while those in English included Smeaton's works on wind and water power, as well as several books and Royal Society papers on agriculture and industry. Those European engineers outside of Great Britain had access to a wide variety of published material, though there was nothing which explained the economics and technology of canal construction in England. The early craftsmen engineers in England rarely published details of their work. It was the change from the full-time employment of the craftsman engineer by canal companies, to those engineers becoming part- or full-time consulting engineers, that may have led to an increase in the number of English language publications, as individual engineers sought to promote and advertise their skills. One source of information was the publication of patent details, and from 1794, *The Repertory of Arts and Manufactures* provided an overview of these. However, they were highly variable in usefulness, often with impractical ideas with a few calculations using simple mathematics. Even as late as 1865, the catalogue for the Library of the Institution of Civil Engineers contained relatively few English language books covering technical aspects of civil engineering involving such mathematics.

Experimental analysis was also much more advanced elsewhere. For instance, when the tunnel on the Canal de St Quentin at Riqueval was first being proposed in France, a whole series of experiments were undertaken into the effect of channel width and depth on the force needed to move a boat, and the results were published in 1777 in *Nouvelles experiences sur la resistance des fluides*. Although the French Revolution and the Napoleonic Wars do seem to have slowed the publication of technical books in Europe, their production certainly did not cease, with Maillard producing several on important aspects of engineering: as already mentioned, in 1784, *Théorie des machines mues par la force de la vapeur de l'eau*; then in 1800, *Methode nouvelle plus courte et plus simple... Mécanique*; followed in 1806 by, *Sammlung von Versuchen...Cemente und Cementmörtel...*; and in 1817, *Anleitung zu dem Entwurf und der Ausführung schiffbarer Canäle*, and in the same year, *Die Mechanik der Gewölbe...*, as well as writing smaller essays, such as *Remarks on Carnot's Attachment*, and *Mémoires sur la poussée des voûtes*. These were all subjects of great interest at the time, and suggest that he was at the forefront of civil engineering.

### *Technical education*

Technical education relies upon good technical publications, as well as academic research. For the civil and mechanical engineer, both of these were lacking in 18<sup>th</sup> century England, though some such education was beginning to be provided in Scotland. On the mainland of Europe, technical education was well established, though with little appreciation of the need to include craftsmen in such education. This was a major factor in holding back industrial development outside of the UK, and the importance of the craftsman was increasing recognised across Europe as the 19<sup>th</sup> century progressed, with technical education increasingly being provided for the apprentice.



Fairbairn wrote extensively on a wide variety of technical subjects.

recognised across Europe as the 19<sup>th</sup> century progressed, with technical education increasingly being provided for the apprentice.

One of the earliest British engineers to advocate a strong link between academic and practical education was William Fairbairn.<sup>17</sup> He was apprenticed in 1804 to John Robinson, a millwright in Northumberland, and worked in London around 1811. There, he had difficulty with the Millwrights' Society, suggesting that the guild system was still restricting technical innovation in London at a time when such innovation was thriving in the north of England and Scotland. Despite this, Fairbairn did find work, though he left London after a couple of years to gain experience in the West Country and Dublin, before settling in Manchester in 1813. Over the years his business undertook a wide variety of work, from mill building and steam locomotives, to ship building, and his published works show that he was one of the more important proponents of combining academic and practical skills. In his 1861 Presidential address to the British Association, he stated that he wanted to remove '*the anomalous separation of theory and practice*', suggesting that there needed to be a balance between practical and academic education, with a recognition that both are of value.

Another Manchester-based engineer and factory owner who reflects the increasing use of academic study in engineering is James Nasmyth.<sup>18</sup> His education was more extensive, and this was added to by family connections with many Edinburgh-based academics with an interest in engineering. He was Henry Maudslay's assistant from 1829 to 1831, which provided him with an excellent introduction to precision engineering, and he set up as a machine tool maker in Manchester in 1834. Here he developed a mass-production system which allowed him to publish catalogues at regular intervals of the standard tools he made. This was the way engineering economics was progressing, with businesses producing a standard range of products, rather than individual items, reflecting a change from expensive craftsman-made machinery to more economical standardised products. He noted in his autobiography that proper machine tools '*...render us more independent of mere manual strength and dexterity, while at the same time they increased the accuracy of the work ... At the same time they had the important effect of diminishing the cost of production...*' His research into the best angles for cutting tools also shows his more academic approach to engineering, providing information that could be published and thus more widely disseminated.

Consideration of both Fairbairn's and Nasmyth's works show that engineering was changing in the 1850s, with their more academic approach providing a greater number of standardised products which were cheaper and easier to sell. The wider introduction of catalogues for all types of machines is a reflection on this change. However, despite their development of this more academic approach to engineering, there was still a need for apprentice-trained craftsmen, alongside the development of institutions for technical education.

Nasmyth, with his more academic background, did have problems with controlling his workforce, and was keen to get away from reliance on highly-skilled craftsmen, and his development of the machine tool certainly reduced the need for skilled workers during production. However, the need for skilled workers remained, as shown by the Parliamentary Report of the 1841 Select Committee on Machinery, where many textile machine makers were questioned about the quality of English skilled workers, and the increasing number of new developments coming from elsewhere.

W Jenkinson, a machine-maker from Salford, suggested, in answer to questions about improvements made abroad, that though there were foreign designers, their designs were often brought into a more usable condition by skilled workers in England:

*1442. Mr. Stansfield] Do you know any instance where machinery has been copied abroad from models sent from here, and been improved abroad? — There are very few improvements made abroad; they are better inventors. We have had many important inventions from France and from America; those inventions have*

<sup>17</sup> Details of Fairbairn's life are taken from Musson and Robinson, *Science and Technology in the Industrial Revolution*, 1969, ISBN 7190 0370 9, pp 480-488, and Byrom, Richard, William Fairbairn..., 2017, ISBN 978 0 901461 64 3.

<sup>18</sup> Details for Nasmyth are taken from Musson and Robinson, *Science and Technology in the Industrial Revolution*, 1969, ISBN 7190 0370 9, pp 489-509, and from Cantrell, J A, *James Nasmyth and the Bridgewater Foundry*, 1984, Cheetham Society 31, ISBN 0 7190 1339 9, pp224-243.

been brought into action here, which would not perhaps have been in their own country, at least not in that perfection which they now are.

1443. *What class of persons is it that bring the invention into use; is it the operative mechanic? — The machine-maker, by his men.*

1444. *The machine-maker sets the operative mechanic into motion? — Yes.*

1445. *Did you ever know the operative mechanic, in the part of the work that is given to him in the division of labour, suggest any important improvement? — Yes, very often.*

1446. *And the probability would be, that the more practice he had the more improvements he would suggest? — Yes; and the English mechanic is noted for that which you now speak of; because there is an inducement for him to do so; he often gets very liberally rewarded for it.*

1447. *How does he produce his improvement; is it upon paper or in the process of hand-labour? — It is very seldom on paper, but by hand, showing you what he can do, and what would be an improvement.*

Richard Birkin, a lace manufacturer from Nottingham, thought that the training and experience of skilled workers in England was the basis of excellence in design:

2478. *Chairman] Had you an opportunity thus afforded you by witnessing the practical skill of the parties employed as machine-makers or repairers in France, and can you state whether they appeared to be as skillful in those operations as parties whom you were in the habit yourself of employing for the same purpose in Nottingham? — From what I saw of them, my inference was, that they are not at present so skillful; but I do not think that that arises from the want of capability, but from the want of practical knowledge; no persons in our trade can do any thing in it, unless they have had a large amount of practice, and great experience; nothing but experience will enable them to arrive at any degree of excellence in it.*

M Curtis, another Manchester textile machine-maker commented on the American textile industry, which was adopting continuous spinning, rather than the intermittent system using mules found more often in England:

1544. *Chairman] Are we indebted to foreigners to any great extent for inventions in machinery? — I should say that the greatest portion of new inventions lately introduced to this country have come from abroad; but I would have it to be understood that by that I mean not improvements in machines, but rather entirely new inventions. There are certainly more improvements carried out in this country; but I apprehend that the chief part, or a majority, at all events, of the really new inventions, that is, of new ideas altogether, in the carrying out of a certain process by new machinery, or in a new mode, have originated abroad, especially in America.*

He went on to describe the increasing specialisation which was developing in England:

1556. *Chairman] Whence does it arise, that with the ingenuity to invent, foreigners still find it necessary to come here to complete the machines? — It is not the case that parties have come here to perfect the machines; they are perfect, as the foreigner imagines, when he brings them to this country; but when they come here they are placed in the hands of mechanics by different manufacturers in whose separate branch they may have to be applied, and those parties, from the more extensive knowledge they have of the working of the various machines, are better able to perfect them, the workmen generally paying great attention to the different working parts. The plan generally adopted in this country is to subdivide labour as much as possible; that subdivision of labour gives great facilities to the workmen to improve the particular branch to which they are attending, inasmuch as their thoughts are not abstracted and taken away by a diversity of subjects, but they confine themselves more particularly to the machine or the work on which they are engaged, and therefore perfect it. As I stated, we confine ourselves to the making of particular descriptions of machinery, all which are protected by patents; and, confining our exclusive attention to that particular branch, we are the more likely to perfect it.*

W Jenkinson, who made textile machinery in Salford, also noted that there were local specialisations from town to town, and from manufacturer to manufacturer:

1339. *They cannot in London make the machinery which you make in Manchester, generally? — No; they cannot make it to anything like the advantage that we can. Of late years, the system of classifying the*

*making of machinery has gone on to a very great extent with us; one machine-maker often makes one kind of machine his principal study, and another, another; by that means each is able to make cheaper and better than they otherwise could.*

Was such specialisation good or bad for the craftsman? It certainly made it easier for a manufacturer to control their workforce; the skill set of each worker would have been reduced, thus reducing the number of jobs available to them. In manufacturing, the development of machine tools capable of mass-producing identical parts removed much of the skill necessary for assembling new machinery, and would lead inexorably to the wasteful replacable 'black box' of today. Parts that once would have been repaired now end up amongst the rubbish or expensively recycled. Nasmyth, possibly because of his problems with his workforce, was proud that using his new machine tools, he could replace a skilled craftsman with a young boy.

However, as Peter Fairbairn, the well-known textile machine maker from Leeds suggests in his answer, that highly skilled craftsmen continued to be required for the installation and maintenance of machinery. Such men needed to be able to address a wide range of problems, and to provide working solutions within a short space of time.

*3113. Lord Sandon] Does it require workmen as skillful to keep machines in repair as to make them? — Yes, I should say that it requires a more general man than any I should employ in my own works; because in my works a sub-division of labour takes place; I require a good many very superior men, but I can do, by subdividing the work, with some inferior men.*

Such skilled men required not just a high level of intelligence, but also a long period of training. James Cox, a mechanist and iron founder from Manchester, who had spent time working in America, responded to a question about training thus:

*1783. Did you ever take any American who was, when you went to America, ignorant and unskilful, and whom, after your instruction, you left equal to the English? — No, it is impossible for any person to be perfect as an artisan in six years.*

Many craftsmen with a wide range of technical skills continued to be found working on maintenance until after the Second World War. For someone from a working class background with a high level of intelligence, a craft apprenticeship was often the obvious choice for work. However, as access to higher education improved, it became more difficult to attract such people to the craft trades. The closing off of access, without a degree, to a professional qualification for workers who had made their way up from the shop floor in the late 1960s, together with the reduction in the length of apprenticeship to 3½ years, put the final nail into the coffin for industrial skilled workers in Britain. The reasons for the decline in appreciation of the craftsman will be discussed below.

### *The Craftsman and Practical Knowledge*

Contemporary technical books describing in detail the construction of canals in the late-18<sup>th</sup> century are comparatively rare, particularly in English. Canals in England were built by craftsmen who adapted traditional skills handed down from generation to generation. They had no need to set down how to undertake the work they were doing as such information was learnt as an apprentice on the job. As a result, the techniques used by craftsmen are rarely recorded. This was certainly the case for wooden boat building. On the Leeds & Liverpool Canal, such things as 'rocker', a downward curve of a couple of inches on the keel to the centre of the boat which can improve handling on the shallow waters of a canal, were not recorded in either specifications or in books on boat construction. This type of detail was decided upon during discussion between builder and purchaser. In the 20<sup>th</sup> century on that canal, those apprenticed as boatbuilders at Whitebirk,<sup>19</sup> near Blackburn, could become journeymen at one of the boatyards in Liverpool when their apprenticeship finished. There they learnt something of naval architecture, the more academic technical design methods used when building modern boats. However,

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<sup>19</sup> Clarke and Yates, 'Hodson's of Whitebirk', *Waterways Journal*, vol 12, 2010, pp37-54.

when they returned to Whitebirk, they continued building boats using traditional methods. Old habits die hard, and canals were where traditional methods of wooden boatbuilding continued to be used into the 20<sup>th</sup> century, with little influence from more modern techniques. The economics of wooden boatbuilding on canals did not encourage modernisation.

The same can be said for canal maintenance workshops. In general, working drawings for such items as lock gates were only produced for the modernisation of large river navigations, or for canals owned by railways where the engineering department had access to a drawing office. For example, on the Leeds & Liverpool Canal, the surviving records show that one foreman carpenter simply kept a list of the outline lock gate dimensions for each set of gates he was responsible for,<sup>20</sup> all that was necessary as all the carpenters knew how a lock gate was built on that canal.

Technical books published in the 18<sup>th</sup> century and after tended to explain new ideas and technology, rather than the traditional methods in use at the time. Unfortunately, academic historians are trained to rely upon the published word and, when interpreting such sources, often lack knowledge of the skills used in practical aspects of construction and operation of machinery. The earliest steam engines often featured in such books and, as a result, this new technology has probably been given a more important role in the industrial revolution than it may deserve. Little was published about how water continued to be the main source of power for many industries into the mid-19<sup>th</sup> century and beyond, with the result that the use and development of water power is not so well documented in published works as the steam engine.<sup>21</sup>

The same could be said for the role of the craftsman, as published works were written for the theoretical education of professional engineers, rather than the apprentice, who was trained on the job. Yet innovations by poorly educated craftsman continued to be of great importance to industrial development right through into the 20<sup>th</sup> century. Anyone who has worked on the mules and looms of the textile trade will be aware that most innovations were created by skilled craftsmen routinely adding small features to existing machinery, rather than by a complete redesign by an office-based engineer. That had to wait until the late-19<sup>th</sup> century, with the design of automatic looms and ring spinning, both areas where foreign designs were perhaps more influential than those developed in Britain.

Early craftsman engineers certainly had some theoretical knowledge, though Smeaton's experimental work on wind and water mills was unusual. Jessop trained under him, and would certainly have understood the use of theoretical analysis on his work. However, this letter written by him on the 17<sup>th</sup> November, 1790, to Mr Osborne, discussing the water supply for Bristol Docks, does give an insight into how craftsman engineers at that time approached their work:

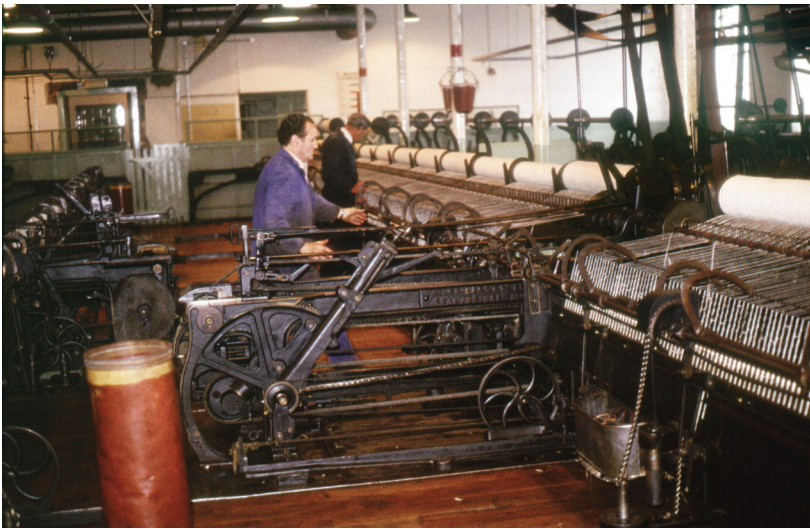
*... To make you compleatly acquainted with the Principles on which the calculations are founded, respecting the discharge of Water over Cascades or through orifices, would take much time and some Study; for having in the early part of my time endeavoured to make myself acquainted with proven principles and having been once satisfied with the Results, I have, as most practical men do, discharged my memory in some measure from the Theory and contented myself with referring to certain practical Rules which have been deduced therefrom and corrected by experience and observation.*<sup>22</sup>

This is an interesting statement, given that at this time steady-state flow of water through orifices and channels was being researched academics, and theories published. But how useful were these theories to an 18<sup>th</sup> century craftsman engineer, and were accurate steady-state flow figures really relevant to the waterway engineer of the time? The answer would certainly be 'no', as water flows would be highly variable and weather-dependent, besides being influenced by any existing user, such as a watermill. When assessing water supply from a stream, a craftsman could easily make a notch or orifice fitted to a wooden channel of known length and section, and then measure the approximate volume passing from

<sup>20</sup> Waterways Archive, BW139-6-11-11

<sup>21</sup> An assessment of the relative use of steam and water power in the United Kingdom can be found in: Kanefsky, J F, *Diffusion of Power Technology*, PhD thesis, Exeter University, 1979.

<sup>22</sup> Quoted in Hadfield and Skempton, *William Jessop, Engineer*, 1979, ISBN 0-7153-7603-9, p226



1984, and yarn is being spun for the first time on the restored condenser mules at the Helmshore Museum, where the author was engineer. The quadrant lever for the cop shaping mechanism has, in effect, been added to an earlier mule design, typical of craftsman-led English textile machinery development. This type of condenser mule was used for waste cotton and was, in detail, more like a woollen mule than cotton, though both used the same basic design.

the time taken for water to travel along this known length of channel. It would then be easy with basic 18<sup>th</sup> century mathematics to calculate the volume of water being supplied over a specific time under specific conditions. But the craftsman would also know that such rates varied considerably, and, as Jessop says, use experience to come up with an answer. Archive material, such as the Tempest Family Papers at Broughton Hall, near Skipton, relating to the Leeds & Liverpool Canal construction, does suggest that canal engineers often relied upon the advice of local farmers and millers when it came to understanding water supplies.<sup>23</sup>

When it came to assessing the annual water supply from rainfall in the relevant catchment area, detailed figures would be rare as meteorology was in its infancy. Richard Towneley, of Towneley Hall, Burnley, was the first to keep regular rainfall records, from 1677 to 1704. Perhaps because of this lack of specific information, the assessment of water supplies for canals was often found to be wanting. However, this could have been the result of traffic on a canal being much higher than initially expected. For example, from their literature, the promoters of the Leeds & Liverpool Canal were probably expecting around 100,000 tons per annum to be carried on the canal, which by 1848 was carrying 2¼ million tons per annum. For canals to cope with additional traffic, reservoirs had to be enlarged and new ones built, or where that was impossible, steam pumping introduced.

Besides water used by boats passing locks, it also had to be supplied for evaporation and leakage. For evaporation, the lack of specific climate records would make an exact calculation difficult, and few craftsmen would have experience of such matters as it had little relevance to water usage prior to canals. The same would apply to leakage, as a craftsman's previous experience would usually have been with rivers. Also, an understanding of how constructing a canal would interfere with the water table and local wells was limited. There was little knowledge of these problem prior to the canal age, though landscape artists creating lakes and water features for stately homes were beginning to realise the effects.

One of the major problems for those technically educated were cultural problems between the academic and the craftsman, and across Europe, the upper classes often had great difficulty when it came to dealing with practical workers. In 1770, when construction was approaching the southern terminus of the Oxford Canal, the committee, mainly made up of Oxford dons and clergy, ordered: *That the Engineer-Surveyor and Clerks of this Company do not associate or drink with any of the Inferior officers or workmen employed by this Company under any Pretence whatsoever.*<sup>24</sup> Had this order been adhered to, it is difficult to know how construction could have continued, and it highlights the problem in communication between the academic and the craftsman.

<sup>23</sup> Clarke, Mike, *The Leeds & Liverpool Canal*, 2016, ISBN 0-9519236-8-4, p262

<sup>24</sup> Quoted in Owens, Victoria, *James Brindley and ...*, 2015, ISBN 978 1 4456 4966 5, from TNA RAIL 855/2, Oxford Canal minutes, 26 July 1770

There were similar problems in France, such as with the location and design of the Riqueval Tunnel on the St Quentin Canal. Petty rivalry between academics adversely affected the work of those actually building the tunnel,<sup>25</sup> resulting in the central section of a canal linking the northern coalfields of France with Paris being virtually abandoned in the years after the first section of the canal opened in 1738. The idea was taken up again by Napoleon in 1801, but it was not until 1810 that the whole scheme, including the tunnel, was completed, and even then it was to need rebuilding before it could be used with regularity.

There were areas where the 19<sup>th</sup> century academic provided much useful research related to the development of new technology, such as industrial chemistry, but the craftsman also continued to offer new insights into the technology. After gaining his doctorate at the University at Giessen, Lyon Playfair moved to Clitheroe to manage Primrose Mill, and in 1841 he set up the Whalley Meeting in his house in that town, a monthly evening meeting to exchange the experiences of local chemists working in the local textile industry. John Mercer was one of those attending, a man who was completely self-taught and whose chemical discoveries were to change the textile industry. Playfair went on to be Professor of Chemistry and Manchester and then Edinburgh, and later noted that Mercer was one of the most intelligent people he had ever met. Intelligence and education are not interdependent.

Later in the century, the craftsman had more difficulty in explaining his ideas as mathematical education for the working man lagged behind that for the academic. Frederick Lanchester had this problem. He made his name by his work on gas engines and gas meters, and had become wealthy enough to be an independent engineer and researcher. He was interested in aeronautics and developed the idea of circulation around a wing, but his grasp of mathematics made his book on the subject almost unreadable, so he was ignored by British academics. However unsound his mathematics, his idea was correct, but acceptance had to wait until Prandtl, in Germany, published his research. It was this rise in the importance of mathematics as technology became more complex which was to mark the change from the age of the craftsman to the age of the engineer.

By the beginning of the 19<sup>th</sup> century, this importance of mathematics was widely recognised in Europe, as Euler's ideas relative to calculus began to be accepted throughout the French and German speaking world. England was much slower to appreciate the benefits to be gained from this new mathematics, and as a consequence would lose much of her lead in industrial development, particularly in the second half of the century. Sebastian Maillard, in Vienna, was at the forefront of using a more mathematical approach to engineering, as his books show. However, most French and German engineers of the time were upper class, and seem to have had great difficulty in explaining their ideas to their craftsmen.

Guild membership also created problems. Both in Europe and in London, the craft guilds were still a force, as mentioned by Haidinger, one of Maillard's companions on his visit to England in 1795, commenting on the decline of the guilds in letter No.12... *So for example, Birmingham does not have coal nor water for its many factories, but Birmingham has no Corporation or Guild, and so it attracted a lot of workers who could not afford the Corporation tax in Sheffield.*<sup>26</sup> It was only in the north of England and the Midlands, where guilds usually had much less power compared to those in London, that craftsmen were able to move freely and quickly between industries, bringing the cross-fertilisation of ideas necessary for industrial development.

Unfortunately, this decline in the status of the guilds led to a decline in the status of the craftsmen in England.<sup>27</sup> Across Europe, and to some extent in London, the guilds were able to sustain the social standing of the craftsmen. When I visit Germany, I explain my technical education as that of a 'Meister'

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<sup>25</sup> Redoni, Pietr, 'Along the Water...', *History and Technology*, 2, no.1, 1985, pp77-110

<sup>26</sup> A translation of the letters can be found in Appendix 1

<sup>27</sup> For the decline in Guild restrictions in York in the 16th century see: Wilson, R G, *Gentlemen Merchants: The Merchant Community in Leeds 1700-1830*, 1971, ISBN 07190-0459-4; For declining influence of the Framework Knitters Company in Nottingham see: Chapman, Stanley D, *The Early Factory Masters*, 1967, David & Charles, Newton Abbott.

— a time-served craftsman — a level of education that they still highly value. In England, where the lack of a strong guild system gave little support to the status of many craftsmen, people in general seem to think much less of them. This lack of social standing has resulted in the current lack of skilled workers throughout much of industry, with society failing to value skills learnt outside of educational establishments. They also fail to recognise that the type of intelligence used academically, based on book learning, is very different to the type of intelligence needed for co-ordination of hand and eye which is required for solving practical problems.

The change from craftsman to engineer which happened in the mid-19<sup>th</sup> century should always be kept in mind when reading Maillard's, and other contemporary technical books. He was working on pushing forward theoretical knowledge of civil engineering, creating mathematical theories to help understand how to design new works. At the same time, he records details of the then current techniques for canal building in more detail than many other books of the period. For example, his description of puddling (paragraph 173) is very similar to that found in specifications for building the Lancaster Canal,<sup>28</sup> suggesting that the clay puddling we accept as normal today was unusual, and puts into perspective Brindley's demonstration of puddling to Members during the time Bridgewater's Canal Bill passage through Parliament. The section on puddling a canal from Rees' *Cyclopaedia*, also reproduced in the Appendix, is from the section on 'Canals' published in 1805, and does show that some practical knowledge was beginning to be recorded in English. However, by 1863 the *Cyclopaedia* was considered of declining importance, the *Quarterly Review* commenting: ...the most extensive cyclopaedia in English... With many excellent articles, it has generally been condemned as on the whole too diffuse and too commonplace.<sup>29</sup> By the second half of the 19<sup>th</sup> century, practical skills were increasingly considered of less relevance.

That the first phase of the industrial revolution was craftsman-led, by men whose intelligence was linked to the co-ordination of hand and eye, not just in undertaking constructional work, but also in the assessment of problems, such as the setting out of ocular surveys for canals, is poorly understood. In Britain, by the end of the 19<sup>th</sup> century, intelligence was being assessed through book-learnt technological knowledge, with the intelligence needed for practical skills considered of much lesser value.<sup>30</sup> These changing values are an important factor to consider when reading technical books of the late 18<sup>th</sup> and 19<sup>th</sup> centuries. To interpret such books effectively, the role of the craftsman must be fully understood.

It is ironic, that at a time when theoretical knowledge was becoming more important to the development of industrial processes, it was the slowness of British academics to adopt new mathematical principles, coupled with the reduction in value put upon practical knowledge, which led to Britain's subsequent decline in leadership in many aspects of technological development.



Coopering, as here at Dukinfield in the 1980s, was one of the last industries to have a traditional apprenticeship.

<sup>28</sup> RAIL844/247, in Appendix 8

<sup>29</sup> *Quarterly Review*, vol.113, 1863, p376.

<sup>30</sup> Buchanan, R A, 'Case studies in engineering training and professional education', *Engineering History and Heritage* 162, Feb 2009, pp29-37



# Endword

So, what does a 200 year old Austrian technical book reveal? One thing it shows is that European engineers were years ahead of those in England when it came to the adoption of more advanced technological mathematics. However, they were not as practical, and were from the 'upper' strata of society. A major factor behind the establishment of the industrial revolution in England was the freedom and social standing open to craftsmen, as well as their ability to understand and create technology suitable for the time. Such craft freedoms were not found outside of the United Kingdom, and they may have resulted from the English political and social upheavals of the previous 100 years — the Civil War and the subsequent Restoration, and the resulting encouragement given to religious, financial and social freedom, particularly in the north of England, away from the influence of the politics, financial institutions, and the Church and Guilds in London, the industrial and scientific centre of England in the early 18<sup>th</sup> century.

Existing London-based centralised institutions were not to have a major effect on the industrial revolution. In London, success was seen as emulating the aristocracy, with their financial independence and their land ownership, so being involved with manual trades was, and to a great extent still is, considered detrimental to social position. Eighteenth century British engineers, coming from the ranks of the craftsmen, managed to overcome this social stigma to some extent, but most remained on the fringes of the social scene. Perhaps they were too hard at work to become involved, though the siblings of the families of many successful engineers and industrialists did purchase large country estates and enter politics, neglecting or selling their family's industrial interests.

It is noticeable that few British engineers travelled outside of the country. Europeans already had their own engineers, who were technically more advanced than those in Britain. Their social class made it difficult for them to interact with those actually constructing or operating industrial machinery, so they needed British craftsmen, and their practical skills. These skills flourished in Britain, a small country, where industries were often being confined to specific areas, which made the transmission of novel ideas much simpler than on the continent, where there were often large distances separating similar factories, making it difficult for craftsmen to access new ideas.

The skill of British craftsmen was widely recognised, as is seen by Becquey's thoughts on the subject noted on page 164, and it was their knowledge which was sought. However, social and language barriers resulted in few being able to make the transfer to the European mainland successfully. One who did was William Cockerill and his family who established the internationally famous Cockerill Company in Belgium, the family undertaking work across northern Europe. British knowledge was also sought for railway construction, though to some extent it was railway contractors who were in demand, with their practical knowledge of the organisation of long-distance civil engineering works.

From the mid-19<sup>th</sup> century, as industrial processes became more complex, it was the earlier adoption of new and more advanced mathematics by European engineers which allowed them to catch up with, and sometimes overtake, technical developments in England.

Consideration of late-18<sup>th</sup> and early-19<sup>th</sup> century engineering books allows us to evaluate the impact and importance of British engineers of the time. It suggests that it was the practical nature of our craftsman engineers which was key to the development of the industrial revolution, and that this lead was lost due to the inability of Britain's academics to adopt advanced mathematics during the early 19<sup>th</sup> century. As academic interest in technology developed in Britain, there was an associated decline in the recognition of the importance of the craftsman and practical skills. This led to the decline in British industrial success in the 20<sup>th</sup> century, and to the skill shortages which the country is suffering from today.

