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COAL AND STEAM - THE ARRIVAL OF STEAM POWER IN STROUD'S WOOLLEN MILLS

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Introduction

As elsewhere in Britain, with the passing years, the woollen cloth industry in Gloucestershire (much of which was packed in and around the five valleys that radiate out from the town of Stroud) gradually evolved from a cottage- to a factory-based system of production. Initially, mechanical power in local cloth mills was only adopted to drive mainly fulling stocks, although ensuing technical developments meant that gradually, power became applied to a growing number of stages of the manufacturing process. Unsurprisingly, throughout this transition, the importance of a reliable source of power increased dramatically.

What was used to provide this power? From time immemorial, this had been provided largely by hand, although in some areas, processing machinery driven by animals such as horses also came to play a role. However, it was the widespread adoption of water power that was to be crucial to the overall development and expansion of the industry as a whole. This was first applied to driving fulling mills in the Stroud region at some point during the 13th century. Water power had its clear advantages in that once the infrastructure was in place, it was essentially a free source of power. As such, it reigned supreme for several centuries although inevitably, there were often problems of seasonal gluts or deficits. It was not uncommon for water mills to be brought to a halt through by, at one extreme, seasonal droughts, or at the other, flooding of the building or back-watering of the water wheels. Particularly where large textile mills were concerned, this meant lost production, with the inevitable financial penalties. Clearly, a more reliable and controllable means of providing power to mills was required to ensure that these large capital investments were capable of operating round the clock. In many parts of Britain's woollen districts, this was to eventually take the form of steam power, although the development and application of engines suitable for driving textile mills was often a slow and expensive business.

Humble Beginnings – Pumping Engines

The first steam engines applied to textile mills were based on Savery and Newcomen-type designs and were used to pump water from the water wheel's tailrace back into the mill pond for reuse. The first reasonably reliable engines were developed early in the 18th century; the first date of installation into a textile mill remains obscure although it may have been during the 1780s (1). At this stage, engines had not been developed sufficiently to directly drive textile machinery hence were limited to this type of operation. During the 18th century, many Yorkshire mills adopted this form of auxiliary engine and at least 35 such examples are known (mainly in textile mills) before 1800 (2). Their consumption of coal was heavy but despite this, they clearly found favour in a number of locations. In 1712, coal consumption for a Newcomen engine used for pumping duties was around 32lbs of coal per horse power per hour (3), an indication of the very low efficiency attainable.

Such pumping installations typically relied on engines of small power (usually 4-6hp), and generally, were only pressed into service when seasonal water shortages demanded it. Apart from Yorkshire, there is little to suggest that this system was adopted widely in other woollen districts although there may have been the odd example in Wiltshire. For instance, at Home Mills, Trowbridge, sales particulars of 1885 mention four engines, one of which was a 12hp beam engine associated with a wheel house containing an 18ft diameter overshot water wheel. The River Biss, at this point, would have been unable to provide a sufficient head of water for

such a wheel (4), so it appears that the engine was used to pump water up to the wheel. Precisely why such an archaic system survived in use up to this late date is not known; however, it does suggest that at least one pumping installation was operating in Wiltshire. Another relatively late survivor was still working c1820; this had been suitably improved with automatic valve gear and was powering a workshop in London (5).

In Gloucestershire, there is no documentary or archaeological evidence to suggest that such pumping systems were ever installed, and the first definite reference to a steam engine in the county did not come until 1799 (albeit in Bristol). Doubtless the enormous coal consumption of these early engines significantly reduced their attractiveness for many West Country manufacturers (6). However, overall, the lifetime of the pumping engine was relatively short and apart from exceptional circumstances, it seems unlikely that many survived beyond the first few decades of the 19th century. Later developments were to produce several variants that were capable of applying rotative motion directly to machinery (see for instance Ref. 7). In Gloucestershire, all of the first batch of steam engines used for powering cloth mills were supplied exclusively by Boulton & Watt (8).

Steady Progress

So, by the latter part of the 18th century, the initial tranche of crude steam engines had taken the first tentative steps towards breaking the woollen industry's almost total dependence on water power and as the 19th century progressed, reliability and power output was gradually improved, increasing the attractiveness of this form of power. As a result, the ratio of water to steam power used to drive textile mills began to change significantly. However, this pattern of change was not uniform and significant differences occurred both within and between the various cloth-producing regions.

Increasingly, as competition in the textile trades from both within Britain and overseas heightened during the 19th century, a dependable, economic supply of power and the capacity for 24 hour operations increasingly became a necessity. The attraction of a reliable form of power was obvious, but both water installations and steam engines could entail heavy investment. Water power had provided significant advantages over hand/animal power although clearly not without its obvious drawbacks. Similarly, when steam began to erode water's long established monopoly, it was sometimes a case of replacing one set of problems with another, and early engines could be unreliable and expensive to erect and operate. However, they were to establish a base of experience from which later developments would eventually spring.

The Situation in the Stroud Valleys

The woollen mills closely distributed along the Stroud valleys relied predominantly on water power for much of their working lives. Its relatively easy availability was perhaps the most crucial factor in the industry's initial development in the area and, in some cases, it continued to play an important role well into the 20th century. Its use was both extensive and widespread, with water-powered mills varying enormously in both scale and output. Inevitably, during the 19th century, as the local industry began to contract and reorganise in the face of growing competition, steam power began to assume greater importance. However, around Stroud, its adoption was slow compared with Yorkshire and even Gloucestershire's more traditional local competitor, Wiltshire. Unlike these two regions, steam power was rarely adopted as the primary source of power, often merely acting as a supplement for water power in times of shortage. Several factors help to account for the slow take-up of steam, some related to the attitudes of the Gloucestershire manufacturers themselves and others to the retarding effect caused by the high cost and difficulties associated with obtaining reliable supplies of coal in the Stroud valleys.

Compared with textile manufacturers in the North, the scale of investment during the second half of the 19th century was considerably less in Gloucestershire, and most Stroud businesses were much smaller than their counterparts in the North. This inevitably restricted funds available for the adoption of what may have been perceived by some as a relatively unproven and unnecessary form of technology. Overall, the reasonably reliable water supplies around Stroud, combined with manufacturers' reservations about steam, combined to greatly impede the latter's adoption in the region and in this early period, only a few of the larger local manufacturers took to steam with any enthusiasm. Gloucestershire's major competitors, in the shape of Wiltshire and Yorkshire, generally took to steam with open arms (Figure 1). However, in the Stroud region, its progress was much slower. In fact, some parts of Gloucestershire's woollen districts never actually got to the stage of installing steam power. Such was the situation with the numerous small cloth mills in and around Painswick where steam remained notable by its absence. However, intriguingly, it seems shortly before the final demise of cloth making in the area, one mill may have been on the brink of adopting steam power, for in 1840, sales particulars for Painswick Mill included:

"...a new steam cylinder and sundry castings for a 20 horse power steam engine" (9).

Table 1 gives an indication of the confirmed steam horsepower available in Gloucestershire woollen mills during the period 1802-1870. The figures for the first half of the century are comparatively reliable, most of the early orders being well documented in the Boulton & Watt order books, a period when they were the main (although not exclusive) supplier to the region. Thereafter, it becomes increasingly difficult to segregate new engines from those already installed. Further complications also arise where, for instance, older engines were uprated or compounded in order to boost output. Thus, the accumulated figures for each year cannot claim to be exhaustive (and are probably on the conservative side), having been totalled up from assorted sources such as the Boulton & Watt records, local engineers order books, the Victoria County History and documents held in the Gloucestershire Record Office and County Library.

As the 19th century progressed, a single engine became less of a novelty and became increasingly accepted simply as another piece of mill equipment. It also became more common for a multiplicity of smaller engines to power parts of sites or individual buildings. For instance, the 1858 spinning mill of Longfords Mill was powered by such an engine (10). In many documentary sources, there may be passing mention of an engine or even none at all. Despite its incompleteness, the figures help confirm that a great burst of engine installing took place in the 1820s and 30s.

Table 1. Total Steam Horsepower in Gloucestershire Woollen Mills (1802-1870)

Year	1802	1803	1805	1814	1815	1817	1818	1820	1823	1824	1825
	6	30	44	64	84	104	114	176	422	490	670

Year	1826	1833	1834	1837	1843	1845	1850	1861	1867	1870
	700	915	927	1015	1033	1093	806	1079	1954	922

Thus, there was a steady, almost linear growth in the uptake of steam power throughout the first half of the century and steam power, on a cumulative basis, generally continued to rise up to the late 1860s. After this date, it fell rapidly, reflecting the contraction of the local woollen industry.

The Scarcity of Coal

One of the main reasons for the slow uptake of steam power around Stroud was undoubtedly the price, and perhaps more importantly, the relative scarcity of coal in the region.

During the 18th century, the appearance of the steam engine had created a whole new market for coal, with major industrial consumers taking increasing tonnages. The market increased substantially after Watt's adaption (in 1781) of the steam engine to rotary motion, resulting in many new uses, particularly in the country's textile mills (11). Coal consumption, especially with early engines, was high and of the 2500 engines in operation in the country before 1800, the average coal consumption was 20lbs per horse power per hour. By the end of the 18th century, typical consumption by the various types of engine was:

- Newcomen-type reciprocating engines 25lb coal per hp per hour
- Boulton & Watt-type reciprocating engines 12.5-15lb coal per hp per hour
- Boulton & Watt-type rotative engines 22lb coal per hp per hour (11)

As engines were increasingly refined, so their efficiency increased and coal consumption fell; by 1856, this averaged out for the various Boulton & Watt-type engines at ~12lbs. The development of a market for "engine coal" had been of considerable benefit to many collieries, as engines were generally fired on small coal that had hitherto been largely valueless to mine owners.

At different times, the price of coal at the pithead varied widely throughout the country, although even where coalfields were separated by considerable distances, general fluctuations in prices were mirrored (Table 2):

Table 2. Regional Pithead Coal Prices 1882-1913 (shillings + pence/ton) (12)

Date	Lancs & Cheshire	Yorkshire	South West
1882	5s 10d (29p)	6s 6d (33p)	7s 0d (35p)
1885	5s 6d (28p)	5s 0d (25p)	6s 7d (33p)
1890	8s 2d (41p)	8s 9d (44p)	10s 1d (50p)
1895	6s 5d (32p)	6s 5d (32p)	7s 7d (38p)
1900	10s 9d (54p)	10s 1d (50p)	13s 1d (55p)
1905	7s 4d (37p)	6s 8d (33p)	9s 5d (47p)
1910	8s 6d (43p)	7s 8d (38p)	9s 11d (50p)
1913	10s 3d (51p)	9s 5d (47p)	10s 9d (54p)

Clearly, much of the South West was at a distinct disadvantage, although pithead prices only paint part of the picture as subsequent transport costs (either by road, canal, rail, or combinations of these) need to be added. In the Stroud region, the transport costs could form a considerable part of the as-delivered price, widening the gap still further. Overall, there were significant regional differences between coal prices with the more isolated regions, such as parts of Somerset, being characterised by prices well above the national average (13). Despite the

high costs associated with many parts of the West of England clothing districts, once steam power had been adopted, there was no going back. A shortage of coal for whatever reason, could lead to near-panic amongst mill owners wherever they were located. As the industrialist George Elliot commented in 1872:

"If there is a scarcity of coal you are on your beams end; you do not know what to do; you must have it at any price" (14).

From these comments it becomes apparent that demand could be relatively unaffected by price, such was the importance to mill owners, many of whom in Wiltshire were, by now, totally dependent on steam. No coal meant no production, whereas in Gloucestershire, where some water power capacity had been retained, at least some production could be achieved.

The figures in Table 2 help to emphasise that, depending on the area, the price of coal could fluctuate widely with time, and even within a particular region, significant differences could occur. Local circumstances such as proximity to a canal could greatly affect prices. In Gloucestershire during the first half of the 19th century, although there were wide fluctuations at times, coal prices averaged between 17-21s/ton (85-105p/ton). Despite the fact that part of the county was rich in coal (the Forest of Dean), prices around Stroud remained relatively high as a result of the monopolies associated with the Forest coal masters. The result was that coal was also brought into the area from the Midlands coalfields and Newport in South Wales. In both cases, add-on transport costs could form a significant part of the total purchase price.

The Impact of Local Canals – The Stroudwater Canal

It is well established that the often poor state of many local roads hampered the development and expansion of the local cloth trade. Clothiers were generally reliant on road transport into the area and there were frequent reports (for instance in 1763) of a:

"great scarcity of coals [that were] often only available at 18s to £1 a ton, a price little short of extortionate" (15).

Once the Stroudwater Canal had been opened to Stroud, the situation began to improve and Rudder comments on the "vast increase of the consumption of coals" and the doubling of the consumption of raw materials used in the local woollen industry" (16).

In pre-canal days, coal from the Forest of Dean, the Midlands and South Wales was delivered to Framilode, on the banks of the River Severn, in Severn Trows. From here, it was carried by wagon a distance of 8-15 miles, depending on its destination, to the various valley mills. Needless to say, a variety of factors increased the uncertainty of supply, ranging from the weather to the poor state of the local roads. Land carriage from Framilode resulted in additional costs, and in 1756, carrying coal to Stroud incurred charges of 7s/ton (35p/ton) in Summer and 8s/ton (40p/ton) in Winter, a considerable extra burden (17). Proponents of the Stroudwater Canal at the time suggested that canal carriage would reduce this to 3s 6d/ton (17p/ton).

Even before the canal's eventual completion in 1779, the Stroudwater Company was advertising for a supplier to provide 10,000 tons of coal to be delivered to the various wharves (18). Even then, it was self-evident how important coal was going to be, both to the local industry and the canal company itself. From the start, the company directors, many of whom already had links with the local cloth trade, ensured that a suitable strategy was put in place. They were intent that recurring coal shortages would become a thing of the past and were convinced that the availability of such a large tonnage would reduce prices in the region and provide sufficient

competition to drive down the high prices previously charged by local coal merchants, a continuing complaint of the local manufacturers. It was also envisaged that such large amounts of coal at competitive prices would stimulate further demand by encouraging the industry to increase its use (19). The company further encouraged its wider use through deliberate pricing policies. For instance, when the canal had reached the Bristol Road wharf, about half way to Stroud, the company declared that:

"All coals sold to waggons at a price not exceeding 12s 6d/ton shall be free of wharfage, and all sold above that price shall pay one shilling per ton" (20).

House coals were invariably more expensive than engine coal; hence the above was probably an attempt to boost the industrial market through a deliberate pricing strategy.

Once the Stroudwater Canal was open, mills bordering it were able to take full advantage of its proximity. Along the lower Frome, coal for Hicks' Eastington mills was unloaded into a central coal pen close to Meadow Mill, from where it was carted to the other sites (Figure 2). Upstream, coal for Bonds Mill was unloaded directly from boats into the mill's bunkers (Figure 3). Later, when the Thames & Severn Canal had been opened along the Chalford Valley, many mills were able to do likewise. However, although the opening of both canals helped to drive down coal prices in the area, parts of the region were still some considerable distance from either the canal itself or from centralised stocking points in and around Stroud. Thus, the numerous mills along the Nailsworth valley still relied on coal brought in by wagon, a clear disadvantage.

Despite reduced coal prices, because of its locality and transport issues, the region still remained at a disadvantage compared to Yorkshire. However, unlike some other manufacturing areas, it was still blessed with a relatively reliable supply of water power. In the region, apart from some locations in, for instance, the Wotton clothing district that were bereft of water-powered sites, few local mills were built specifically as steam mills. Even what constitutes one of the last major mills to be rebuilt in the region, Stonehouse Upper Mills of 1875, still installed water wheels as well as a steam engine.

That the opening of the Stroudwater Canal would have an impact on coal prices in the region could never have seriously been in doubt. Immediately prior to its opening, coal prices in Stroud were often in the 19s to £1 2s/ton (95p to £1.10/ton) range (21) assuming that it was available at all. By the time that the construction of the canal had reached the Chippenham Platt wharf at Eastington, coal was often available at 13s-3d to 15s/ton (66p/ton to 75p/ton), and even with the addition of 3s 6d (18p) haulage costs to Stroud, this remained a step in the right direction. By the time the canal reached Ryeford Wharf near Stonehouse, Shropshire coal was selling at 13s 9d/ton (69p/ton), Forest of Dean at 14s 9d/ton (74p/ton), and best Staffordshire at 15s 3d/ton (76p/ton) (22). Clearly, the Stroudwater Canal was having a major impact on reducing coal prices charged to local industry and perhaps more importantly, of ensuring that regular supplies were now reasonably well assured. The impact on local mills varied, depending on their location. Those in the immediate vicinity benefited most, whereas those in outlying districts still faced additional haulage costs.

The Thames & Severn Canal

Within a few years of the Stroudwater's opening, it had been joined end on at Wallbridge by the Thames & Severn Canal, which carried on via the Chalford Valley, joining the Thames at Lechlade. Like the Stroudwater, importation of coal into the area was to be a major part of its working life. The canal company built a large central base of operation known as Brimscombe Port, part of this including an island on which coal was stored securely. As with mills lower

down supplied by the Stroudwater Canal, those (especially in the Chalford Valley) benefited from some reduction in coal price. In 1811, prices at Brimscombe Port were (23):

- Bullo coal, Forest of Dean 18s/ton (90p/ton)
- Lydney coal, Forest of Dean 20s 6d/ton (102p/ton)
- Newport, South Wales 21s/ton (105p/ton)
- Staffordshire 23s 6d/ton (118p/ton)

Prices were certainly lower than in pre-canal days although mill owners in the region still remained at a substantial disadvantage to their peers in Yorkshire as secondary transport costs often continued to inflate the pithead price significantly.

Initially, coal was carried to Brimscombe Port in lighters laden with 45-50 tons. It took 1-2 days for each to travel from Framilode to Brimscombe. Later, the "Stroud barge" appeared, a vessel of suitable dimensions, capable of carrying up to 60 tons of coal to Stroud, Brimscombe or Chalford (24). The peak year for coal carried on the Thames & Severn Canal was c1850; thereafter, tonnages gradually declined. Throughout the canal's working life, coal remained the main cargo and although manufacture in the area undoubtedly benefited from reduced coal prices, throughout the history of the Stroud industry, these were to remain considerably higher than those in the North.

The Arrival of the Railway

The opening of the two local canals helped to reduce coal prices and helped stabilise its supply, and it might be expected that the coming of the railways to the Stroud region might have had a similar impact. However, even though the Gloucester-Birmingham Railway was opened in 1840 (swiftly joined by the Gloucester to Bristol line) and the Great Western's Bristol-London line was opened in 1841, there was to be little immediate impact on the cloth producing regions, both in Gloucestershire and Wiltshire. Despite the usefulness of these main lines, the lack of branch lines into the clothing districts meant that there was still no facility for the direct transportation of coal. Where coal was carried by the railways, it still had to be carted from centralised stocking points, often some considerable distance from local mills. This resulted in further delays and additional carriage costs. It was not until 1845 that a branch was built linking Stroud, c1848 when one reached Trowbridge, and not until 1857 that the railway arrived in Bradford-on-Avon, both the latter already being almost totally dependent on steam power (25). In the Stroud region, as with the canals, the Nailsworth valley remained devoid of a rail link and it was not until the eventual opening of the Stonehouse-Nailsworth Railway in 1867 that the town's relative isolation was ended. However, this was too late to be of much use to the cloth trade in the area which by now, was in a state of steady decline. Elsewhere in the region, where mills were still at work, a number of spurs were taken off the main lines, allowing coal to be transported directly into their sites. For example, the sprawling Cam Mills site was linked by rail to the main Bristol line at Coaley Junction and similarly, Stanley Mills had its own spur, enabling coal to be unloaded directly into the mill's bunkers.

The Retention of Water Power

Even though the pressure on manufacturers in the Stroud region to install steam power increased over the years, even the larger manufacturers had often been reluctant to abandon existing water powered systems and switch entirely to steam. The result was that overall, Stroud had a long-running dependence on water power, steam in many instances being installed mainly to supplement water power in times of seasonal shortages or when power requirements outstripped the existing water power capacity. The decision to install steam power was not always an easy one and was very dependent on the particular circumstances. If the owner had sufficient capital

to proceed, and many of the smaller ones did not, this could be a risky proposition, especially if the mill was only marginally profitable. If the gamble did not pay off and the hoped-for increase in profits failed to materialise, the spectre of bankruptcy was never far away. In addition, the existing mill building(s) may not have been structurally suitable for the adoption of a large, bulky steam engine. The add-on costs could be substantial and involve considerable alteration to the fabric of the building or the expense of an add-on engine and boiler house (Figure 4). Under such pressures, some manufacturers collapsed, others left the industry because they lacked the capital, and others retired to the peace and quiet of landed property (26).

Clearly, from an early date, the North had embraced steam power with a vengeance. There were a number of reasons for this substantial uptake, one of which being that many of the streams supplying water-powered sites were very variable, their flow fluctuating throughout the year (27). As important as this was, it was the easy availability of inexpensive supplies of coal that really pushed steam to the fore. However, even where coal was not available in the immediate vicinity, transport costs remained relatively low (compared to the West of England), especially as the railway network expanded in the region. For a time, even crude pumping engines with their enormous appetite for coal could be tolerated in the North, whereas they could rarely be countenanced in the West.

For the woollen industry to operate in a particular area, it became crucial that controllable, reliable power was available. In Yorkshire it was steam power and in Gloucestershire, it was water augmented by steam. If a region had neither, it soon withered away. Even as early as the 1830s, a Select Committee reported that as a result of lack of access to adequate water power and/or inexpensive coal, the woollen industry had largely migrated from various southern counties such as Suffolk and Essex, mainly "to northern districts where coal for engines is much cheaper".

Throughout the first half of the 19th century, steam power continued its inexorable rise in the North and by 1838, was providing a significantly greater percentage of power requirements than water. During this period, in much of the West of England (Gloucestershire in particular) water continued to play an important role. In 1838, Gloucestershire was producing ~500hp from a large number of water wheels rated 20hp or less, whereas Yorkshire was generating ~1200hp. The Somerset and Wiltshire woollen districts were each generating around half of Gloucestershire's output. Water wheels of >20hp were found in relatively small numbers in Gloucestershire (with only a few up to 40hp) but in greater profusion in Yorkshire; such wheels were almost totally absent in other regions. However, it was in terms of steam power that the differences between the clothing districts became very apparent. Yorkshire had many engines ranging from <10hp up to 50hp, whereas Gloucestershire had a meagre number, mainly in the <10-20hp range; there were few exceptions to these figures (28). Thus, the West lagged far behind the North and even in Wiltshire, where steam power had made a greater impact than in Gloucestershire, the reliance on steam power was nothing like as great as in Yorkshire. Although steam was now providing the greater percentage of power in Wiltshire, in Gloucestershire, the percentage of power produced by water remained much greater than that produced by steam.

Concluding Remarks

Writing in 1871, Fairbairn was in no doubt as to the overall position:

"The steam engine as an instrument of propulsion is at the present time of such vast importance as to sink into insignificance every other known agent as motive power...the whole of water power in Great Britain falls immeasurably short of that obtained from steam, in every

department of useful art...It is now thirty years since it was found desirable to increase the power of steam engines employed in manufacture, and instead of engines of from 20 to 50 nominal horse-power, as much as 100, and in some cases 200 horse power were required to meet the demand" (29).

Despite Fairbairn's comments and the clear message it carried, at least in parts of the Gloucestershire woollen districts, water still remained an important source of power although inevitably, its dominance was to wane in the face of steam power. Later, in turn, local dependence on steam itself gradually declined as alternative sources of power such as oil and gas engines became available, although their impact on the local woollen industry was relatively small. A process of slow change saw steam gradually replaced mainly by electrical power. This was either generated on site or from public supply. However, overall, for much of their working lives, many local cloth mills relied on combinations of water and steam power. The use of water power in the Stroud valley woollen mills greatly outlived that in most other textile districts, and unlike many other regions, co-existed alongside steam power for a significant part of the local woollen industry's history.

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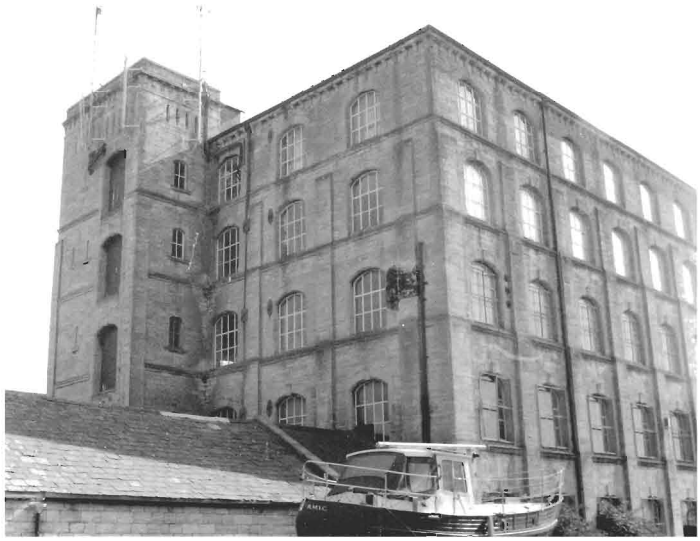

Fig . 1 Studley Mill, Trowbridge, one of many steam-powered mills serving the Wiltshire woollen industry

Fig . 2 A laden coal boat approaching Pike Lock and Bridge, Eastington. The local coal merchant's yard is on the left, immediately before the bridge

Fig. 3 Bonds Mill, Stonehouse, c1930. The close proximity of the Stroudwater Canal is clear

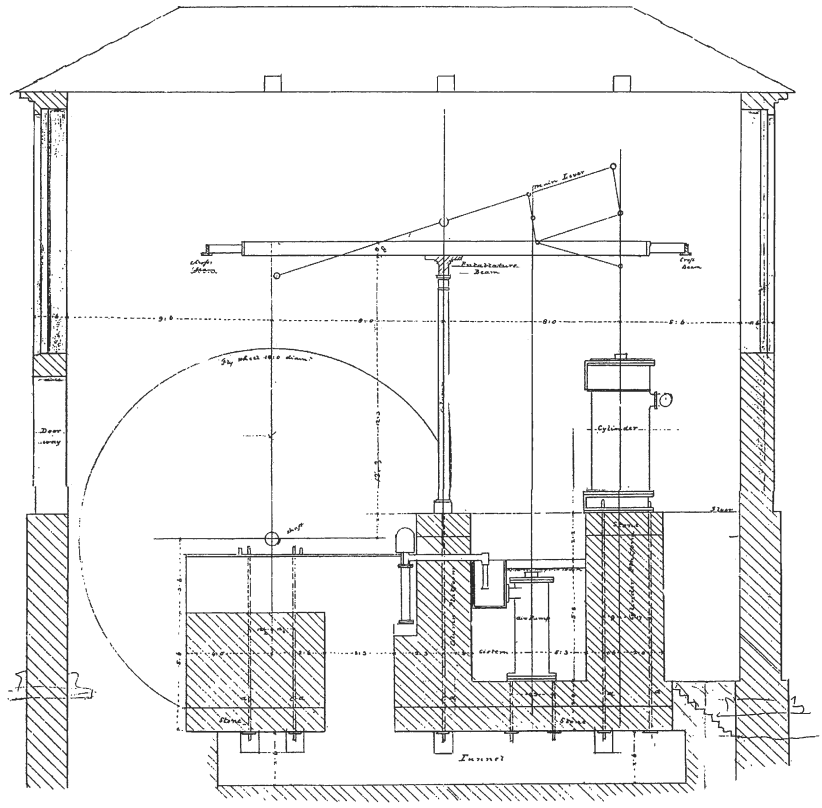

Fig. 4 Plans from the Boulton and Watt order books for the new engine house added to an existing building at Churchend Mills, Eastington, 1822