Industrial Archaeology Review

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/yiar20

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To cite this article: Ian Miller (2024) Salford Twist Mill: Uncovering an Iconic Textile Factory, Industrial Archaeology Review, 46:1, 18-34, DOI: 10.1080/03090728.2024.2357425

To link to this article: https://doi.org/10.1080/03090728.2024.2357425

Published online: 05 Jun 2024.

INDUSTRIAL ARCHAEOLOGY REVIEW
2024, VOL. 46, NO. 1, 18–34
https://doi.org/10.1080/03090728.2024.2357425

Salford Twist Mill: Uncovering an Iconic Textile Factory

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ABSTRACT
The Salford Twist Mill of 1799–1801 has attracted much attention as a pioneering example of an iron-framed building, the first textile mill in England to have benefited from steam heating and one of the earliest buildings in the world to have been permanently lit by gas. Aspects of the mill's development have been debated since its destruction in the mid-20th century, although several points of contention were clarified during an archaeological excavation and associated research conducted by the University of Salford in 2016–17. In particular, fragments of structural ironwork recovered from demolition layers yielded fresh evidence for the building's internal cast-iron frame, and excavation of the engine room enabled details of the power-transmission system to be elucidated. Whilst this article necessarily recites earlier work, it combines the key findings from the recent investigation with a review of previous studies to provide a definitive account of one of the first iron-framed mills.

KEYWORDS
Salford; George Lee; fireproof mill; iron frame; gas lighting; excavation

Introduction

Several significant technological innovations that helped to define the form of the early steam-powered textile factory were pioneered at the Salford Twist Mill. Hailed as one of the largest cotton mills in the Manchester manufacturing district by the early 19th century, the Salford Twist Mill comprised three multi-storey blocks that were built in separate phases commencing in 1790 to create a continuous linear range that was approximately 124m long by 1801. The last of the three multi-storey components, erected in 1799–1801, was of especial note as it was the first mill in Lancashire to be of 'fireproof' construction with brick arches springing from cast-iron beams that were supported by two rows of cast-iron columns.[1]

The diffusion of cast iron in the construction of textile mills and the development of the first generation of multi-storey buildings with iron frames in the 1790s is a topic that has elicited much academic attention previously.[2] Mills required strong columns and beams to carry heavy machinery and materials, but stout timber sections used in the construction of traditional industrial structures were becoming scarce and expensive by the late 18th century and cast iron offered a versatile and cheaper alternative. The replacement of timber with structural iron also reduced the risk of a catastrophic fire consuming the building, which was especially important in the context of a textile mill where cotton dust, rags, lubricating oil-soaked timber floors and candles or oil lamps used for illumination was an inflammable combination, evidenced by the frequent loss of mills to catastrophic fires during the late 18th and early 19th centuries. The incombustible cast-iron frame supported floors of brick arches that were typically covered with rubble and flagstones to create what became known as 'fireproof' construction. Whilst it is mistaken to consider that this ground-breaking construction technique guarded mills completely from destruction by fire, it nevertheless set the standard for what became the most prevalent construction system for industrial buildings through the 19th and early 20th centuries.

Writing in 1854, the renowned engineer and 'indefatigable protagonist of iron' William Fairbairn stated that the Salford Twist Mill was designed by Boulton & Watt in 1801 and was the first iron-framed building in the world, a claim that was reiterated in several notable works on the topic that were published in the mid-20th century.[3] Whilst there is no doubt that the mill deserves considerable acclaim for its technological innovation, Bannister makes a compelling argument for William Strutt's six-storey Derby Calico Mill of 1793 to have been the first prophetic example of a multi-storeyed iron-framed structural system with the floors all being constructed on brick arches and supported by two rows of cast-iron columns, although the transverse beams were of Scots pine.[4] Unfortunately, the building was demolished in the 1860s without any detailed record of its structural components. A second early 'incombustible' mill cited by Bannister was also erected by millowner-engineer William Strutt at Belper in 1793–5, replacing his father's original cotton mill of 1776.[5] Known as the West Mill, the new building was nearly 58m long, 9.45m wide and six storeys high, comprising brick arches springing from timber beams supported by cast-iron cruciform columns. The columns were set in two rows along each floor, forming three longitudinal aisles and 23 transverse bays with a span of 9ft (2.74m).[6]

The Shrewsbury Flax Mill erected at Ditherington in 1796–7 is widely recognised as the first true iron-framed building that employed cast-iron beams in place of timber.[7] The building was 54m long and 12m wide with an internal frame that was entirely of iron. The beams were cast in two pieces bolted together in a large cross-flange on the centreline of the building and supported by three rows of cruciform-section cast-iron columns. The brick vaulting on each floor sprung from the iron beams that incorporated a bottom flange with a prismoidal skewback cross section.[8] The mill was designed largely by Charles Bage for the flax-spinning partnership between John Marshall of Leeds and Thomas and Benjamin Benyon of Shrewsbury, and whilst he acknowledged invaluable advice received from William Strutt, Bage clearly 'understood the strength of cast iron better than his contemporaries' and deserves to be credited with designing the first true iron-framed building.[9]

Mention should also be made of the enigmatic Crag Works in Wildboarclough, Cheshire, which has been dated to between 1793 and 1799 through documentary research and therefore broadly contemporary with the Shrewsbury Flax Mill. The building was visited during its demolition in 1958 by J.H. Massey, an architecture student, who reported that the mill floors had been supported by cast-iron beams, although the evidence was drawn from an anonymous oral account as the building had been

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cleared before Massey's visit who was therefore unable to examine the structure and confirm that the iron beams had formed part of the building's original frame.[10]

The Salford Twist Mill post-dates all the examples above but nevertheless incorporated some ground-breaking innovations in its design, although certain key aspects of its structural history have been a topic of debate following its demolition in the mid-20th century. Some of this uncertainty has been resolved by an archaeological excavation and associated research that was undertaken by Salford Archaeology in 2016–17 in advance of the site's redevelopment.[11]

Initial Development of the Salford Twist Mill

The origins of the Salford Twist Mill can be traced to 1790–2 when the Salford Engine Twist Company erected a purpose-built mill for the preparation and spinning of cotton. This occupied the south-western part of a plot of land on the north-western bank of the River Irwell in Salford (centred on NGR SJ 83485 98535), situated on the fringe of the late medieval town in an area that experienced intensive development during the late 18th century (Figure 1).

The founding partners of the Salford Engine Twist Company were John and George Philips, Charles Wood and Peter Atherton. The Philips family had established themselves as Manchester's leading exporters of textile goods such as smallwares, fustians, checks, muslins and calicoes in the early 18th century, whilst Charles Wood was similarly a prominent local merchant and manufacturer of checks.[12] Peter Atherton contributed different experience to the partnership, having gained renown as one of the most successful textile-machine makers of the later 18th century.[13] He established a business in Warrington during his early career, where he was famously approached by John Kay and Richard Arkwright in 1768 for assistance in creating a model of a spinning machine as producing some components were beyond Kay's technical ability.[14] He invested in several enterprises subsequently, including Atherton & Co. that operated cotton mills in Warrington and Liverpool, and also owned cotton mills in Chipping and Holyhead. Atherton has been credited with being the first really successful designer of the earliest generation of steam-powered textile mills in the 1790s.[15] In view of these credentials, Peter Atherton will undoubtedly have played a significant role in developing the Salford Engine Twist Company's first mill, with the Philips family and Charles Wood supplying much of the financial backing.

The mill was six storeys high, including a basement, and was of brick construction with timber beams with internal dimensions of 33.83m by 10.67m. The mill was designed to spin cotton twist on Arkwright-type water frames, which is unusual in Manchester and Salford where these machines were 'largely ignored in favour of the cheaper and more adaptable mule'.[16] The adaptation of the spinning mule from a hand-powered machine to one that could be driven by a steam engine, however, is attributed to John Kennedy in *c.* 1793 whilst working as a machine maker in rented premises in Ancoats before he progressed to establish one of Manchester's most successful large-scale cotton-spinning firms in partnership with James McConnel.[17] The date of Kennedy's success in adapting the mule to steam power, perhaps coupled with Atherton's experience of water frames in use in some of his other mills, explains the choice of spinning machinery for the original Salford Twist Mill.

The mill was one of the earliest factories in the Manchester district to have been powered by steam, although it has been suggested that the engine was used initially to raise water from the River Irwell onto an overshot waterwheel rather than powering the machinery directly.[18] The evidence to support this assertion is not given, and whilst a 'wrought-iron bucket waterwheel' of unspecified dimensions is itemised in just one of the numerous advertisements for the sale of the mill and its machinery that were printed in local newspapers during the mid-1840s, it seems unlikely that a waterwheel employed to power the mill some 50 years previously will have been in a condition to attract a resale value.[19] Records in the Boulton & Watt Collection, moreover, show that the engine was a 30hp (22.4kW) double-acting model with 'sun and planet' gearing that was suitable for powering the spinning machinery directly rather than being intended to pump water.[20] The agreement to erect the engine with a yearly payment of £150 was signed in May 1791 and it became the first engine built by Boulton & Watt to be delivered to Salford.[21]

Correspondence with Boulton & Watt in 1791 records that the engine was ordered for 'Peter Atherton of Liverpool and partners', although Atherton later explained that the Salford firm was 'not yet fixed' and the engine was intended for the Salford Twist Mill rather than one of his other mills. Peter Ewart, one of the leading practising millwrights of the 1790s and an agent for Boulton & Watt in Lancashire, informed John Southern in a letter dated August 1792 that he 'undertook to execute all the millwork and drums of Messrs Atherton & Co's mill in Salford for £600', but admitted that it had actually cost £200 more than he had estimated.[22] The mill in question was most probably the Salford Twist Mill, and whilst Ewart does not provide a date for the work it would seem likely that the power-transmission system had not been completed until the summer of 1792.

George Augustus Lee and the Second Mill

The successful expansion of the mill following the completion of the first factory was due largely to the acumen and engineering talent of George Augustus Lee, who became a partner in the Salford Engine Twist Company in 1792. George Lee was born in 1761 and gained note for his 'intuitive perception of the advantages to be derived from applying to useful purposes the great inventions that distinguished the era in which he lived, and the rare faculty of directing them, with energy and perseverance, to the fulfilment of extensive and important designs'.[23] It was during George's youthful years that great advances in textile machinery were achieved and the world's first successful cotton-spinning factory was established by Richard Arkwright and partners at Cromford in 1771.[24] The following years saw a plethora of water-powered mills being set up to spin cotton twist on the Arkwright model; an estimated 143 mills of the same principle were in operation by 1784, including a mill on the River Weaver in Northwich in Cheshire that was set up by Messrs Cockshott & Co. in 1780. This mill was bought in 1782 by Peter Drinkwater, who emerged as one of the most influential of Manchester's late 18th-century factory owners although, according to Robert Owen, he was 'a good fustian manufacturer and a first-rate foreign merchant' but 'totally ignorant of everything connected with cotton spinning'.[25]

George Lee's first recorded employment was as a clerk at Drinkwater's cotton mill in Northwich. In 1789, Drinkwater established Bank Top Mill, also known as Piccadilly Mill, which is widely acknowledged to have been the first cotton mill in Manchester to have been powered by a rotary steam engine supplied by Boulton & Watt.[26] Drinkwater appointed George Lee as manager to supervise the installation of the machinery and the operation of the mill, Lee having been recognised not least by Drinkwater as 'a very superior scientific person in those days'.[27] George Lee sent a letter from Northwich in October 1790 to inform James Watt junior that he had agreed terms with Drinkwater, suggesting he commenced in his new role at Bank Top Mill shortly afterwards.[28] Lee was evidently in Manchester by May 1791 when he wrote to James Watt junior regarding repairs to the engine and reported that he was still awaiting millwrights to arrive.[29] George Lee left Drinkwater's employment in 1792 at the invitation of George Philips to become a managing partner of the Salford Engine Twist Company. Lee will doubtless have brought invaluable

Figure 1. Extract from William Green's *Plan of Manchester and Salford Drawn from an Actual Survey* of 1787–94 depicting the Salford Engine Twist Company's first mill, with inset marking its location on modern mapping (© University of Salford).

experience of fitting out Drinkwater's mill with machinery and also a personal connection with James Watt junior, which became a valuable and lifelong association. Once at Salford, Lee will have benefited from working with Peter Atherton for a year or so before the latter retired from business in March 1794.[30]

George Lee progressed the first extension to the Salford Twist Mill in *c.* 1795 with the addition of another six-storey block against the south-eastern end of the original building, which became known subsequently as the Old Mill. The extension had an increased internal width of 13.11m, reflecting its intended use for mule spinning. The firm returned to Boulton & Watt to discuss an engine for the new spinning block, with George Lee placing an order for a 20hp (14.9kW) model in October 1795. A short hiatus in progress thereafter may have been due in part to uncertainty in the cotton trade as a result of over-stocked markets and a reluctance amongst merchants to place large orders until the outcome of peace negotiations with France was made clear. This was coupled with a growing scarcity of cash and the resultant introduction of the Bank Restriction Act of 1797, with many cotton spinners in the Manchester area resorting to 'short time' working.[31] The cotton trade improved during the second half of 1798 when George Lee resumed discussions with Boulton & Watt and changed his engine order to a 30hp (22.4kW) model; the average rating of an engine supplied by Boulton & Watt for use in a textile mill during this period was 18.2hp (13.5kW).[32] John Southern at Boulton & Watt advised a customer in January 1800 that 'it has been the custom about Manchester to reckon a horse equal to turning 1000 mule spindles with preparation', suggesting that the Salford Twist Company's new spinning block may have been designed to house 30,000 spindles.[33]

The order for the 30hp engine was finalised in December 1798 and Boulton & Watt supplied a design drawing in January 1799. The engine was duly erected alongside the firm's original engine, to which it was connected, and was at work by August 1799.[34] By that date, George Lee had turned his attention to erecting a third mill, which was to be of a revolutionary design.

The Cast-Iron Framed New Mill

In a letter dated 10 March 1798, George Lee informed James Watt junior that it had been agreed at a recent meeting with his partners that he should 'immediately erect another mill', and whilst he then added 'their hearts have since failed' the foundations for the New Mill were nevertheless laid and the walls completed up to the level of the first tier of beams in 1799.[35] The footprint of the mill was considerably longer than the earlier buildings and extended north-westwards from the Old Mill. It was to be of seven storeys, including a basement, each storey forming a room 63m by 12.80m with an engine room across the north-western end (Figure 2). There was then a hiatus in construction work until June 1800, but the walls had been completed to their full height and the internal frame installed by November of that year. Cast-iron columns and beams were employed throughout the New Mill with the exception of the roof trusses, which were of timber construction.

It has been argued that the short hiatus in construction work at the point of installing the first-floor beams is significant as it was during those months that George Lee made the decision to use iron beams in the structure of the New Mill.[36] It was also during this period that Lee afforded brief but serious consideration to diversifying into flax spinning, exchanging several letters with James Watt junior on the topic.[37] He also met with John Marshall and almost certainly visited Charles Bage on two occasions early in 1800, which enabled him to describe the workings of the Shrewsbury Flax Mill in a letter to James Watt junior and conclude that his New Mill would be larger.[38] It is therefore likely that the break in construction work enabled Lee to refine some of the technical design detail for his New Mill in light of discussions with Marshall and Bage, coupled with a tour of their Shrewsbury mill, although the evidence available in the Boulton & Watt Collection suggests that he had intended to employ cast-iron beams from the onset. The initial drawings of the mill were prepared by George Lee, which he had shared with Boulton & Watt by May 1800, seemingly with an intention of eliciting their comments on the design. Lee's drawings showed each transverse beam to be of two sections, joined together at mid-span, with a cross-sectional profile identical to that used by Bage at Shrewsbury. Having reviewed the design, James Watt recommended that three beams should be used instead of two, joined at the supporting columns, with the columns passing through the joint. Watt also suggested that the ends of the beams should have circular eyes to clasp to the top of the columns.[39]

Detail of the completed iron frame before the brick vaulting and mill gearing were added is captured in a remarkable perspective drawing that was produced at Lee's request early in 1801 by William Creighton, one of James Watt's draughtsmen (Figure 3). This informative drawing was based on a measured cross-section and whilst some of the detail apparent on Lee's earlier drawing seems to have been refined, including the increased width of each bay from 12ft 10in (3.91m) to 14ft (4.27m), both iterations clearly show the beams jointed at mid-span, implying that Lee had rejected some of James Watt's advice. This further suggests that George Lee assumed overall responsibility for designing the mill and not Boulton & Watt, as posited by Fairbairn, although Lee undoubtedly benefited from Watt's advice.

Creighton's drawing also shows that the iron beams were supported by cylindrical columns, which were structurally more efficient than the slender cruciform cross-section type that they superseded; the Salford Twist Mill was probably the first textile mill to have employed such columns.[40] It is uncertain whether their introduction can be attributed entirely to George Lee, although it is known that these hollow columns were also used as conduits for steam to warm each of the floors in the New Mill. Boulton & Watt is widely accredited with supplying the steam-heating apparatus in 1802, although there are no design drawings surviving in the firm's extensive archive and the 'evidence' appears to have been inferred from a letter written by George Lee to James Watt junior in January 1802 asking him to advise his father and John Southern that steam had been 'admitted to the building and the elongation was as expected 1/10th of an inch per 10 feet nearly'.[41] Lee is also reputed to have applied the same system to heat his house, implying that he had a thorough understanding of its workings and may actually have been responsible for its design rather than Boulton & Watt.[42]

In the absence of any original drawings, details of the steam-heating system and its operation are uncertain. It may be presumed that the steam was raised in the boilers that served the mill's engine, and was perhaps admitted to the columns in the basement via the flanged connections shown on Creighton's drawing. Another feature of note sketched by Creighton is a vaulted tunnel beneath the basement floor, which was probably intended to serve the steam-raising plant with water but may also have been employed to drain condensation from the steam-heating system.

It is well documented that Boulton & Watt supplied the engine and boilers for the New Mill, together with the gas lighting, but it is not known if the firm was commissioned to cast the iron beams and columns. Whilst tempting to assume that was the case given the correspondence between George Lee and James Watt junior on the topic of an iron frame, there are no documents in the Boulton & Watt Collection to demonstrate that anything other than sketches and advice were provided. There were certainly foundries in Salford and Manchester that were capable of casting the iron components for the New Mill, not least the Salford Iron Works of James Bateman and William Sherratt, who were also Boulton & Watt's main competitor for supplying steam engines in the Manchester manufacturing district.[43]

The ground-floor arches were erected in March 1801, but the foundations of a column failed in July, causing one fatality and demanding significant remedial works to the foundations. Annotation on a drawing in the Boulton & Watt Collection notes 'solid stone built after the failure of July 27, 1801', although there are no details of the work conducted. Any alterations to the configuration of the cast-iron frame drawn by Creighton following the failure of the column are similarly absent from the documentary record.

The initial plan had been to power the New Mill with a 60hp (44.7kW) engine, but an entry in Boulton & Watt's order book dated 20 August 1800 was for a 70hp (52.2kW) model. This was uprated again in February 1801, perhaps reflecting the pace at which the capacity of spinning mules increased during this period, with the final order being for a 100hp (74.4kW) engine, referred to by George Lee as 'Ixion'.[44] This was the largest engine for a textile mill recorded in the Boulton & Watt Collection until well into the 1820s, and implies that the New Mill had been intended to house 100,000 spindles, with the spinning mules presumably arranged transversely across each floor.[45] The final design drawings show the engine to have incorporated a crank rather than 'sun and planet' gearing, a 24ft (7.31m) diameter flywheel, a 48in (1.22m) cylinder with an 8ft (2.44m) stroke, parallel motion and a cast-iron connecting rod (Figure 4a). Notably, the engine had an iron rather than a timber beam and is likely to have been one of the earliest engines that the firm built entirely from iron. The plans also show that the steam-raising plant was to include four wagon-type boilers that were to be installed in the basement next to the engine room at the northern end of the mill. A transmission shaft along the centreline of the basement presumably supplied power to the machinery on the ground floor, whilst a vertical shaft housed in the engine room transferred power to the upper floors (Figure 4b).

The New Mill was completed by the end of 1801 and the machinery was mostly in place by April 1802, according to information in letters written by George Lee to James Watt junior. By that date, the Salford Engine Twist Company had been rebranded

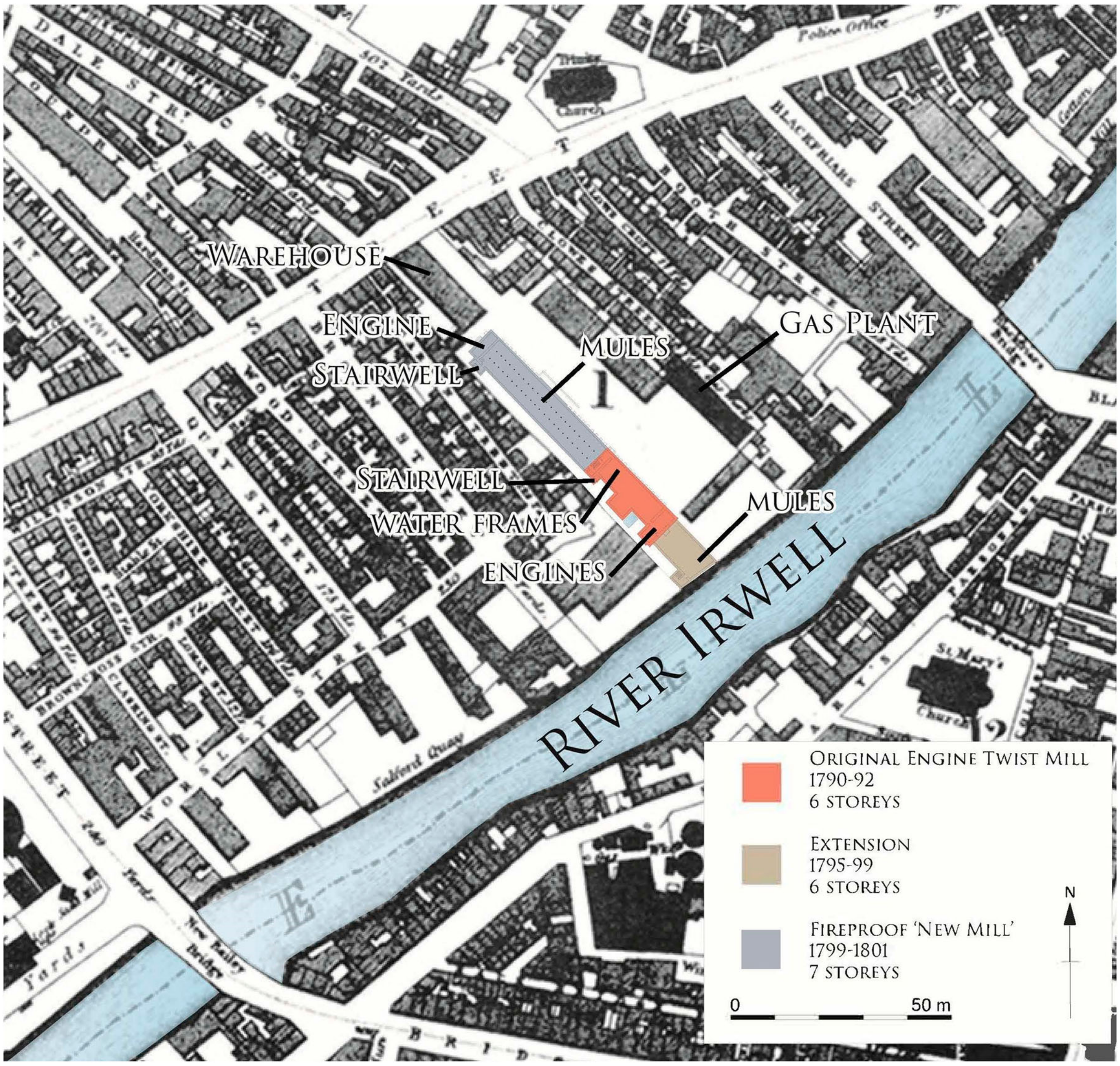

Figure 2. The main components of the Salford Twist Mill superimposed on Bancks & Co.'s *Plan of Manchester and Salford* of 1831 (© University of Salford).

as Philips, Wood & Lee, although a further change to just Philips & Lee implies that Charles Wood had left the partnership by February 1806. It was also during this period that a five-storey building referred to subsequently as a 'fireproof warehouse' was erected.[46] Very little detail is known about this warehouse, although it was later reported that the gable end fronted Chapel Street and it measured 'about 120ft in length and 40 ft wide' (39m x 12.8m), corresponding with the footprint of a building shown to the north-west of the New Mill on Bancks & Co.'s map of 1831 (Figure 2). Another building erected next to the mill by the early 1800s was a new house for George Lee and his family, who had lived previously at 39 Broken Bank in Salford, just over 1km to the west of the mill.[47]

Gas Lighting

It is widely acknowledged that the principal developments in gas lighting can be attributed to William Murdoch, the son of a Scottish millwright who became an engine erector for Boulton & Watt in Cornwall in 1779. Murdoch experimented with gas as a source of lighting whilst in Cornwall, illuminating his home successfully in *c.* 1792 with gas distilled from coal heated in an iron pot.[48] Murdoch continued his experiments after moving to Birmingham in 1798 to work at Boulton & Watt's Soho Works, where he was assisted for a short while by Samuel Clegg and, in 1802, famously included two gas lamps in the exterior illumination of the building to celebrate the Peace of Amiens.

George Lee had expressed an interest in Murdoch's experiments as early as 1800, and in 1805 he placed an order with Boulton & Watt to supply gas-lighting apparatus for the Salford Twist Mill, part of which was installed in late December of that year to enable 50 gas lamps to be lit on New Year's Day 1806.[49] This was the first commercial gas-lighting plant to be produced by Boulton & Watt and the Salford Twist Mill was undoubtedly the first large factory in the world to be illuminated by gas lights, although Samuel Clegg had installed a smaller plant to light Willow Hall Mill in Sowerby Bridge, which was purportedly working two weeks before that in Salford.[50]

George Lee also had his house and the entrance drive lit by gas and proceeded to carry out extensive experiments on the efficiency of the lights and different types of lamps, their relative brightness compared with candles and the operating costs. Lee presented his conclusions as evidence to the 1809 Parliamentary Select Committee on the Gas Light and Coke Company's Bill, demonstrating the practical and economic benefits of gas lighting even though he appeared as witness for Boulton & Watt, who were opposing the Bill.[51] Lee's evidence of the gas-lighting system at the Salford Twist Mill is very likely to have expediated the adoption of the technology by other mill owners.[52]

Cotton Mills to Bonded Warehouses

Philips & Lee was said in 1813 to be the largest cotton firm in England.[53] George Lee died on 5 August 1826 at the age of 65,

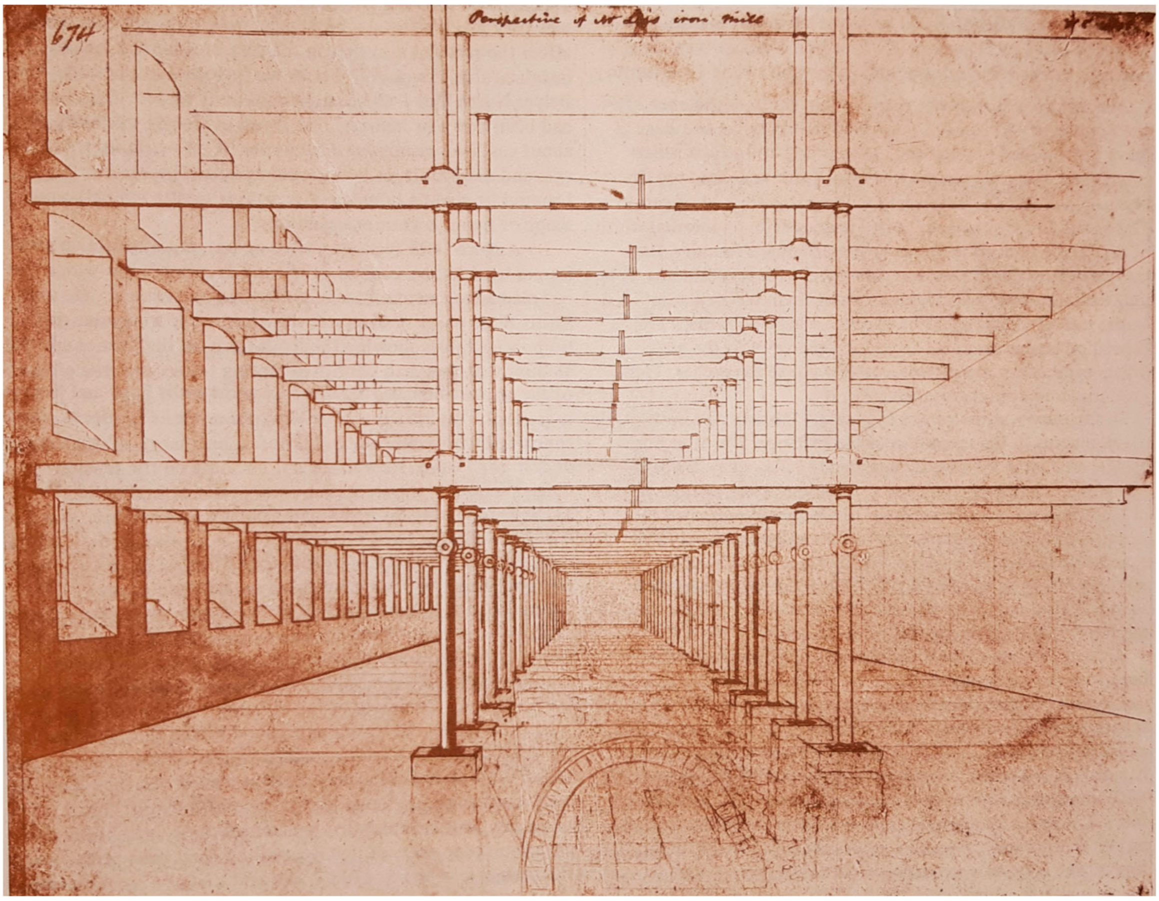

Figure 3. Creighton's perspective view of the iron framing in the New Mill, drawn in 1801 (Reproduced from Tann 1970).

by which date the factory was known as the Salford Cotton Mills and Lee's business partners were Sir George Philips, Robert Philips and Nathaniel Philips, who continued to trade under the name of Philips & Lee.[54] The partnership was dissolved in 1831, suggesting that there was a diminished appetite to continuing business in the absence of George Lee, and the Salford Cotton Mills were rented to Messrs Lambert, Hoole and Jackson.[55] This firm was responsible for replacing the Boulton & Watt steam engines with two new models in 1840, together with updated mill gearing. These engines were built by W. & J. Galloway of

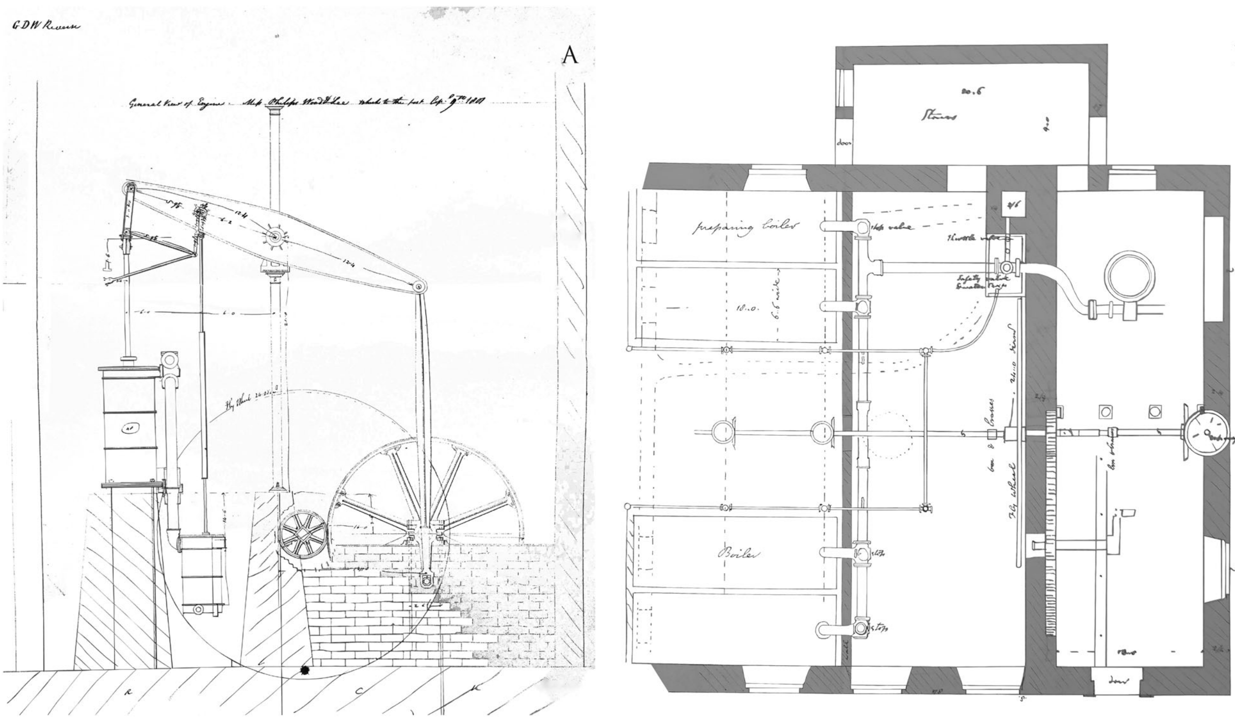

Figure 4. (a) Boulton & Watt section drawing (reverse copy) of the engine for the Salford Twist Company's New Mill, dated September 1801, and (b) plan of the engine, boilers and transmission shafts (Reproduced with the permission of the Library of Birmingham, MS 3147/5/242/c).

Manchester, with one rated at 112hp (83.5kW) and the second 102hp (76.1kW), although is unknown precisely where this new power plant was installed.[56]

John Lambert retired from the company in June 1841 and business was continued under the style of Hoole, Jackson & Charlewood, although this partnership was dissolved by mutual consent towards the end of 1842, likely as a result of a severe depression in trade.[57] The Philips family decided to let the buildings and sell the machinery, which was duly advertised for auction over three days in mid-June 1843. This included ten blowing machines, 195 carding engines (breaker and finisher), numerous drawing, slubbing, roving and stretching frames, together with a variety of spinning machines ranging from water frames equipped with 240 spindles, common throstle frames with 120 spindles, a suite of spinning mules from 276 to 324 spindles and four pairs of Sharp, Roberts & Co.'s self-acting mules, each with 348 spindles. Doubling frames, winding machines and making-up presses were also on offer, together with engineering equipment that included numerous lathes, a drilling machine and wheel-cutting engine, a smith's bellow, anvils, a punching press and an assortment of hand tools.[58] The three spinning mills, the five-storey warehouse, a counting house, turning shop, bale room, gasometer house and an adjoining lodge, together with a large dwelling house, stables and five cottages were all offered for let.[59] It was described as 'the most extensive sale that has taken place in Manchester or the district for many years', yet there was not a single bidder for the mills or machinery.[60]

Another auction in October 1844 was evidently more successful as the machinery was advertised for sale in December of the same year 'in consequence of [the mills] being converted into bonded warehouses'.[61] The machinery included the two steam engines built by W. & J. Galloway and 13 wagon-shaped boilers. The repurposing of the mills was carried out on behalf of the Manchester Bonded Warehouse Company which, according to a notice placed in local newspapers in February 1845, had recently obtained a deed of registration according to the Manchester Bonding Act and was ready to receive goods 'in bond'.[62] Goods that were held by the warehouse during its first year included bales of cotton and silk, tea, coffee, sugar and madder roots, and in 1861 the Commissioner of Customs granted the Company the privilege of bottling wines and spirits for exportation.

In March 1845, shortly after the premises had been taken over by the Manchester Bonded Warehouse Company, a section of the roof on the five-storey warehouse of *c.* 1805 collapsed during repair work. In contrast to the adjacent New Mill, the roof structure of the warehouse was of cast iron, supported by two rows of columns. The columns 'were very slight and from iron cups let into the top of these pillars very light principals of cast iron were carried at a shallow spring to support the roof, or rather roofs, for it was in three divisions'.[63] The warehouse was rebuilt and is identified on Goad's insurance plan of 1893 as 'Trinity House', used in part as a cotton waste warehouse and in part as a spirit warehouse and bottling stores for John Dewar & Sons.

The 'fireproof' New Mill was leased to Render & Co. Ltd, corn and flour merchants, in December 1875 but 'a considerable part of the building gave way' in August 1877. Litigation proceedings concluded that the collapse had resulted from overloading the fourth and sixth floors with flour and determined that it was not due to an inherent defect of construction in the building.[64] The upper floors were reconstructed and the building remained in use as a bonded warehouse. It is widely held that the building survived until the Second World War when it was destroyed by aerial bombing on the night of 21 December 1940, although it has been suggested that the New Mill may have been dismantled long before that date and that the building bombed in 1940 was a later structure.[65] The archaeological excavation of the site in 2016–17, however, confirmed that the New Mill had indeed been destroyed by aerial bombardment in 1940.

The Excavation

The site of the Old Mill and the extension of *c.* 1795–9 lie beneath the modern Lowry Hotel, the development of which in 2001 will have removed any surviving foundations (Figure 5). The sites of the five-storey warehouse and the mill's gas plant were similarly unavailable for excavation, although the footprint of the iron-framed New Mill was in use as the hotel car park. This area lay within the boundary of a proposed development and was excavated by Salford Archaeology in 2016–17 ahead of construction work. An irregular-shaped trench with a total area of 738m^2 was opened to a maximum depth of 3.5m through modern surfaces and a thick depth of demolition rubble to expose the foundations of the north-western part of the New Mill, including a large section of the basement, much of the engine room and a narrow extension to the south-west (Figure 6). The excavated remains charted a sequence of phases in the development of the building.

The Mill Walls

The earliest structures to be exposed included the brick-built foundations of the south-western wall of the mill, which was 0.75m wide and survived to a maximum height of 2.5m above the basement floor (Figure 7). This comprised hand-made bricks laid for the most part in stretcher bond. The wall was punctuated by regularly spaced cellar lights, each measuring 1.96m and tapering down to a width of 1.6m, with their splayed sills set approximately 1.2m above the basement floor. An arched aperture in Bay 10 from the north-western end had been crudely blocked with a mixture of common and refractory bricks, but had probably formed the original entrance to the basement. This may have been sealed off when the mill was converted to a bonded warehouse in 1844 as the detailed Ordnance Survey Town Plan of 1850 does not show an external stair in this location. Earlier plans depict the stair tower external to Bays 1 and 2, but the fabric of the wall in Bay 2 presented no evidence for the stair having continued down to the basement, and the base of a 2.4m square chimney occupied Bay 1 at the junction of the mill wall with that of the engine room.

The foundations for the chimney were set on gravel overlying the sandstone bedrock that lay at a depth of 1.24m below floor level. Internally, the chimney measured 1.5m by 1.25m with the flue mouth in the southern elevation. This had been bricked-up by the mid-19th century and a new flue inserted through the south-western wall of the mill, the position of which was marked by a horizontal iron lintel built into the wall and areas of later brick infill (Figure 8).

The Steam-Power Plant

The engine room across the north-western end of the New Mill was 5.8m wide and separated from the basement by a 0.75m-wide wall of hand-made bricks that survived to a height of *c.* 3.20m above its foundation course. The north-western wall of the engine room was of a similar width and was also entirely of brick except for two vertical courses of large, squared stone blocks that were set 1.86m apart. These blocks were penetrated by several vertical holes that probably marked the anchor points for a large footstep bearing for the first motion shaft and the upright transmission shaft shown on the Boulton & Watt design drawing (Figure 4b). The footstep bearing was likely removed in the mid-19th century when the building was repurposed for warehouse use, and the area between the stone mounting blocks infilled with brick to form the new entrance stairs shown on the Town Plan of 1850.

A brick-built foundation across the engine room towards the south-western end may have been the base of a wall that supported the engine's cylinder. This wall partially overlay a circular,

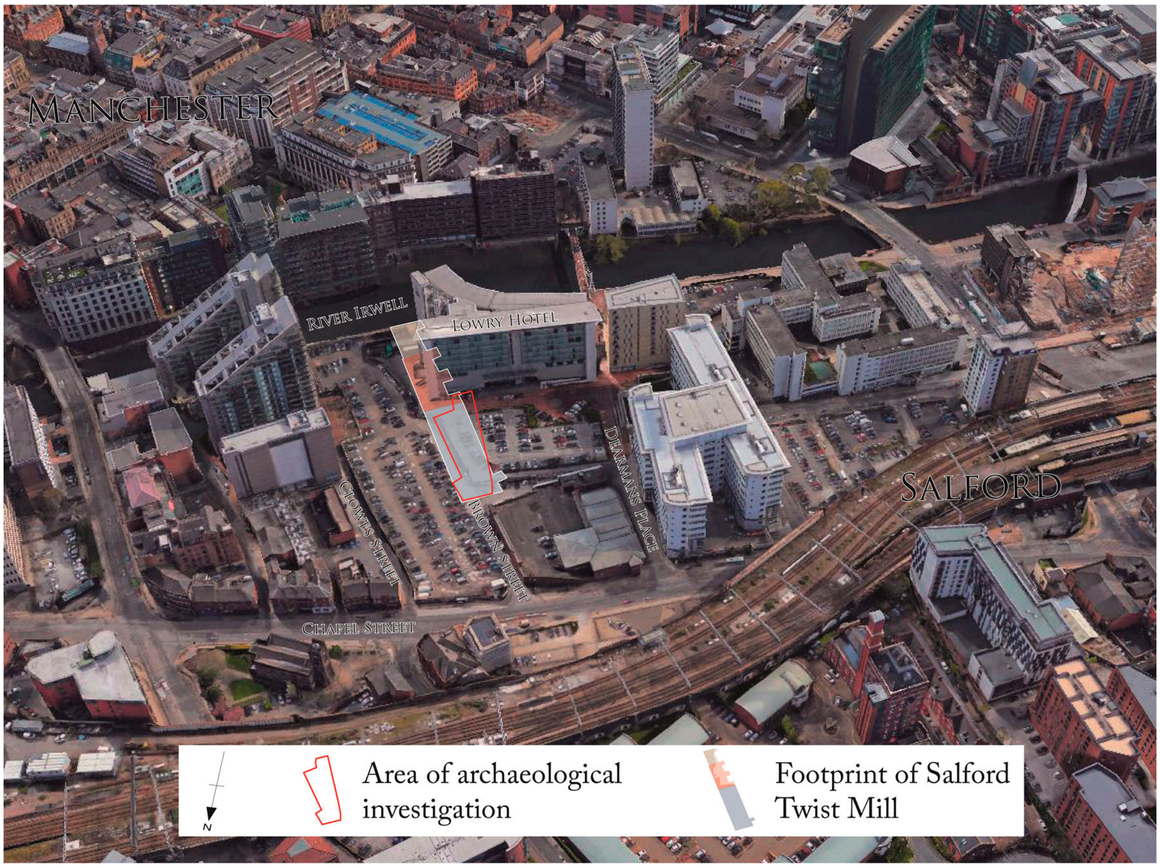

Figure 5. Excavation area superimposed on an aerial view, showing the footprint of the Salford Twist Mill in the modern townscape (© University of Salford).

brick-lined well with a diameter of 1.24m (Figure 9). The vestiges of another brick-built foundation across the engine room to the north-west of the well may have represented the position of the lever wall that had supported the engine's beam. There were very few other surviving fixtures or fittings in the engine room that betrayed its original layout, although an iron bearing box inserted into the north-western wall was tentatively identified as having been associated with the Galloway engine that was purchased in 1840. Abutting the south-eastern wall of the engine room and set into floor across the centreline of the basement, however, was the flywheel pit for the original Boulton & Watt engine. This was just 0.33m wide, with the bricks lining the base laid carefully to follow the curvature of the engine's flywheel.

A section of a brick-built flue beneath the floor and extending from the chimney in Bay 1 survived next to the flywheel pit (Figure 10). The flue walls were 1.2m high and were of rough hand-made brick on the outside but well-faced internally to facilitate the efficient flow of exhaust gases. Fragmentary remains of two other sections of the flue branched off to the south-east and east to serve individual boilers, although no other remains of the steam-raising plant survived. Despite the excavation continuing down to the bedrock across the area of the boilers, there was similarly no physical evidence for the vaulted tunnel shown beneath the floor on Creighton's drawing, which is annotated as a source of water for the boilers on sketch section drawings in the Boulton & Watt Collection dated December 1800 and January 1801. It is possible that the vaulted tunnel was not actually constructed, or it may have been removed during the remedial works carried out in the wake of the documented failure of a column in July 1801 and the subsequent insertion of an additional row of columns. The final design drawings for the steam-power plant that were produced after the collapse do not show how the boilers were supplied with water, but the archaeological evidence suggests that it was not via a vaulted tunnel beneath the basement floor.

The First Cast-Iron Columns

The excavation revealed four parallel rows of bases along the basement, each spaced regularly at 2.74m intervals. These were laid as at least two separate phases, with two of the rows representing foundation pads for the original cast-iron columns that formed 23 transverse bays and three longitudinal aisles, each with a span of 4.27m (Figure 10). Each foundation pad comprised a rectangular stone block measuring 930mm by 810mm with a 510mm square cast-iron base set on top that featured a shallow 250mm-diameter cup, designed to receive the foot of a Type 1 column (Figure 11a). This hollow, cylindrical column type had a 25mm thick wall and a uniform outer diameter of 165mm, increasing to a maximum of 250mm at the closed hemispherical foot (Figure 11b). No complete examples were found during the excavation although, remarkably, the lower parts of three of this column type remained *in situ* along the eastern edge of the excavation area, the upper parts having been sheared off below the flanged connection for horizontal pipes shown on Creighton's drawing (Figure 11c). Fragments of what were likely to be the upper sections of Type 1 columns displayed a narrow rolled astragal just below a rectangular head plate. A central, hollow spigot with an outer diameter of 130mm was cast to the top of the head plate to facilitate a connection with a circular clasp at the end of the overlying beam.

A variation of this column was the Type 1a, a complete example of which measured 2.68m long with a uniform outer diameter of 160mm. A notable difference to the Type 1 was the replacement of the closed hemispherical foot with a round base plate, reflecting that this column had been used on the floors above the basement. A thick-walled, central, spigot similar to that atop the Type 1 head plate was cast to the underside of the base plate of the Type 1a. The top of the Type 1a column had a more pronounced astragal and a slender oval head plate that typically measured 220mm by 190mm and similarly had a circular spigot on top, with an outer diameter of 130mm and an internal diameter of 90mm (Figure 12).

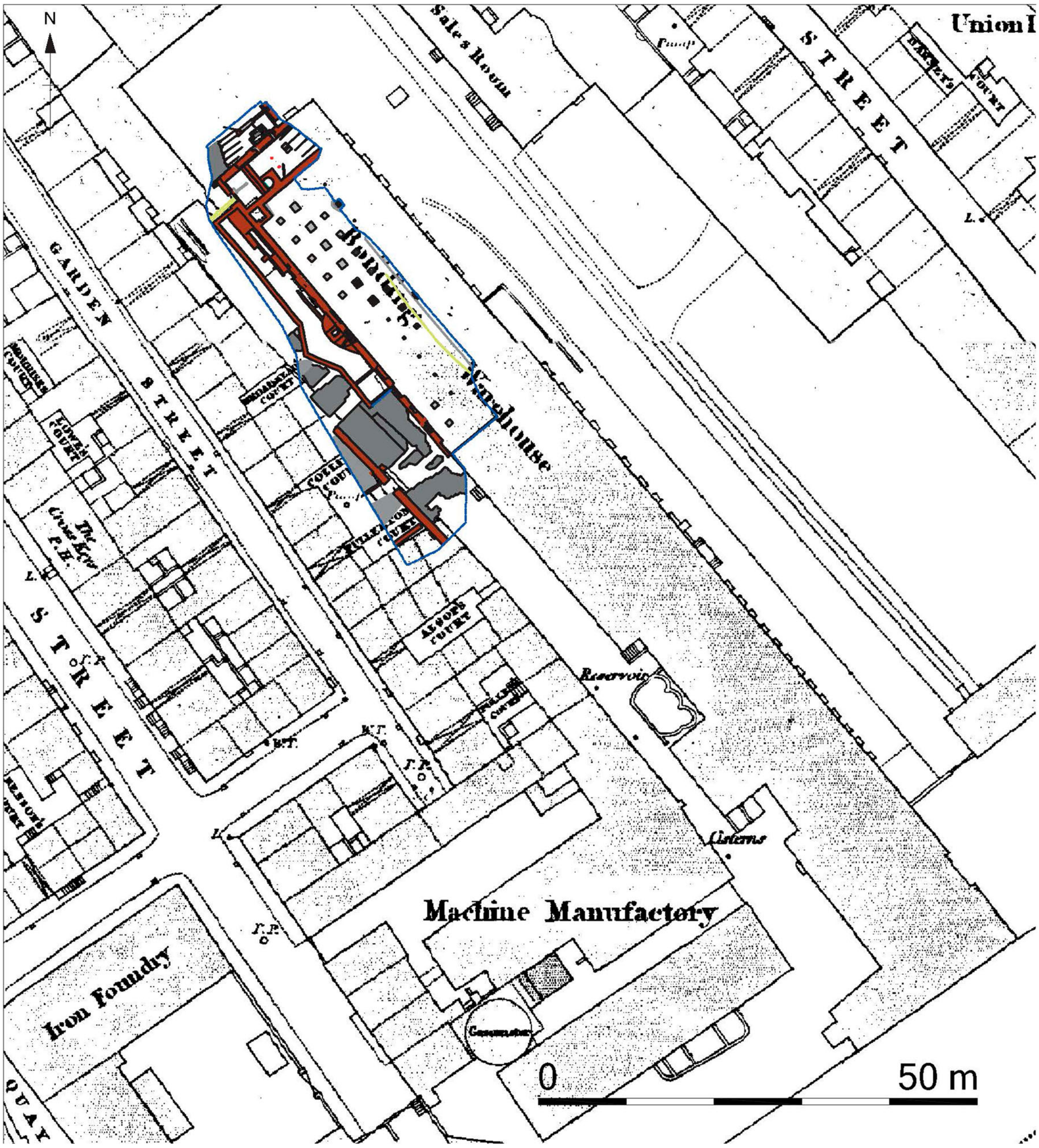

Figure 6. Area of excavation superimposed on the Ordnance Survey 1:1056 Town Plan of 1850 (© University of Salford).

Figure 7. The excavated basement looking towards the engine house and internal chimney, showing the remains of the south-western wall of the mill and four rows of column bases (© University of Salford).

The Cast-Iron Beams

Fragments of several beams derived from the original cast-iron frame were recovered from the excavation, and whilst only one of these was largely complete there was nevertheless sufficient evidence to show how the beams had probably joined together and interlocked with the columns. All of the beam fragments found during the excavation displayed an inverted T-section profile with an 81mm-wide flange along the bottom edge to support the brick vaulting springing from each side. In all examples, the web and bottom flange had a typical thickness of 25mm. The depth of the web of each beam was generally 350mm, increasing to 400mm near the columns, but none displayed the gentle whaleback form depicted on Creighton's drawing of 1801. Several fragments contained a pair of rectangular holes, each measuring approximately 35mm by 30mm and intended to house longitudinal wrought-iron tie rods to counteract any displacement generated from the thrust of the floor arches. Another beam fragment had a projecting bolting eye

Figure 8. The excavated chimney base and blocked flue in the north-western corner of the basement (© University of Salford).

cast onto its vertical face close to the joint with the column, in place of the holes for the tie rods. The position of these housings towards the top of the beam suggests that the tie rods and bolting eyes will have been above the crown of the brick vaulting and therefore not visible.

Creighton's drawing shows two rows of columns creating three longitudinal aisles of 14ft (4.27m) width, which was confirmed by the excavated positions of the original column bases. The beams spanning the basement and ground floor are shown to have been bolted together at the mill's centreline, and there is no reason to doubt that the same approach was taken on the upper floors (Figure 3). Bannister, quoting William Fairbairn's paper of 1854, similarly concluded that the transverse beams were 44ft (13.41m) long, including 12in (0.30m) bearing set into the side walls, and that they were cast in two equal parts and bolted together through end flanges along the centreline of the mill to eliminate 'awkward and weakened joints around the columns'.[66] The detail of some of the fragments uncovered during the excavation, however, demonstrate that the beams had actually been jointed at the columns. Several fragments featured a circular clasp that was 190mm deep and had been cast onto the lower half of the beam (Figure 13a). The clasps had an average wall thickness of 30mm and extended 180mm beyond the end of the beam, seemingly intended to receive the spigot on the head plate of the underlying column. Above the clasp, the end of the beam terminated at a curved sleeve, the arc of which corresponded to the circumference of the Type 1a column base plate thereby allowing it to rest on top of the clasp. The width of the bottom flange increased by 55mm on each side adjacent to the clasp, creating a 125mm-wide plate that was pierced by two 30mm square holes. Some of the clasps retained part of a 120mm-diameter hollow pin with a lip around the top edge (Figure 13b). It is suggested that this hollow pin facilitated a connection between the columns to provide a sealed joint and prevent any loss of the steam that was passed through to heat the mill.

None of the beams with a complete clasp survived to their original length, although it is plausible that those spanning the outer aisles were just over 4.27m (14ft) long when allowance is made for their ends to be set into the mill wall. The single near-complete beam that survived was only 2.13m (7ft) long with a bolting face at one end indicating that this was one of a pair that had spanned the central aisle. The rectangular bolting face measured 330mm by 225mm and had four 30mm^2 square holes for the bolts. Another rectangular plate, measuring 270mm by 185mm and similarly having four square holes, was cast into the bottom flange next to the bolting face (Figure 13c). This is shown on Creighton's drawing and was presumably associated with the power-transmission system. A vertical sleeve cast to the opposite end extended the full depth of the beam in place of the clasp seen on the supposed 4.27m-long (14ft) beams; this beam also retained a bolting eye (Figure 13c). The curvature of the full-depth sleeve cast onto the end of the beam was noticeably wider and of sufficient size to envelope the clasp, sleeve and column on the mating beam (Figure 14). The connection is likely to have been clamped together, although evidence for how this was achieved was not identified in the archaeological record.

Stone Levelling

Creighton's drawing captured the structural detail of the lower two floors of the mill shortly before the column failure in July 1801 that demanded remedial work to the foundations. The archaeological excavation demonstrated that a layer of crushed sandstone had been deposited on top of the bedrock to a depth of 1.6m at the north-west and increasing to a depth of 2.1m in the centre of the mill, presumably representing the natural slope towards the River Irwell. A levelling layer of sand mixed with stone and brick fragments had then been laid to a depth of up to 0.2m on top to form a bedding for the basement floor, although nothing of this internal surface survived. The crushed sandstone and overlying levelling material appeared to have been laid around the existing column foundation pads.

Inserted Cast-Iron Columns

Two rows of bases that were parallel to those for the original columns had seemingly been installed after the stone levelling had been imported. Each base comprised alternate courses of brick and stone blocks that extended to the depth of the bedrock and were capped with 660mm square and 40mm thick stone pads. These formed a solid foundation for 450mm square and 30mm thick cast-iron bases, some of which retained two parallel iron strips on the upper surface (Figure 15a). One row of these bases was placed along the centreline of the mill and may have been foundation pads for Type 2 columns. Four examples of this type were recovered from the excavation, each comprising a hollow cylindrical column that tapered out towards the top, with a 35mm thick and 309mm square base cast to the foot and head. The casting at the column foot incorporated two parallel slots, the size and position of which corresponded with the iron

Figure 9. The excavated remains of the engine house, showing the partition partially overlying a brick-lined well (© University of Salford).

Figure 10. Detail extracted from the Boulton & Watt design drawings superimposed onto a plan of the excavated remains (© University of Salford).

strips on the foundation pad (Figure 15b), whilst the rectangular head plate was flat (Figure 15c). These columns may have been inserted after the column failure of July 1801 to support the horizontal power shaft that passed down the centreline of the basement, whilst simultaneously providing additional support to the bolted joint between the two beams spanning the central aisle. The second row of foundations pads lay parallel to the south-west and were of an identical size and form to the central row, suggesting that they may also have supported columns associated with the power-transmission system in the basement, although there is no supporting evidence.

It is possible in view of the square head plate to the Type 2 column that it was secured to the beam and connected to the overlying column via a crush box. Part of what was almost certainly a crush box bolted to the base plate of a column was discovered during the excavation (Figure 16), although the column appeared to be of a later 19th-century date rather than deriving from the original structure and may have represented a replacement that was fitted after the documented collapse of two floors in the mill in 1877. The use of crush boxes to secure the original Type 2 columns therefore remains conjectural and it is similarly uncertain whether the central line of inserted columns was limited to

Figure 11. (a) Detail of the Type 1 cast-iron columns showing a foundation pad with its cupped base and (b) the hemispherical column foot, together with an example *in situ* (c) along the eastern edge of the excavation area (© University of Salford).

the basement or extended to the overlying floors. The solid base and head plates to the column indicate that this type did not form part of the steam-heating system.

Remodelling in the 19th Century

Documentary references imply that two new steam engines, possibly together with replacement boilers, were installed in 1840. The excavation of the engine room did not yield any firm evidence for New Mill having received a new engine beyond the tentative identification of an isolated bearing box set in the north-western wall, whilst Goad's insurance plan of 1893 shows that the room had been converted for use as stables. Structural remains deriving from mid-19th-century alterations were exposed immediately to the south-west of the mill, however, including a new flue that was built against the foundations for the external elevation of the south-western wall, signalling the relocation of the boilers. The new brick-built flue measured 0.55m wide and was 1.16m high with a flat capping of bricks, and was cut through the mill wall at its north-western end to enter the original chimney in the corner of the basement. This flue was remodelled subsequently and connected to a new chimney that was built to the south, as marked on the Ordnance Survey Town Plan of 1891.

Figure 12. The Type 1a cast-iron column showing the oval head plate (© University of Salford).

Destruction and Demolition in the mid-20th Century

The excavation has shown that the New Mill was reduced to a ruin by an intense fire that almost certainly was caused by incendiary bombs during the Second World War. The mill basement was filled with heavily burned rubble and ash with hundreds of spirit, sherry and champagne bottles. Some were discovered in burned crates packed with straw, whilst other bottles had partially melted and become distorted due to intense heat (Figure 17). The shell of the mill survived wartime bombing, at least in part, as its outline is identified as a 'ruin' on the Ordnance Survey 1:1250 plan of 1949. It had been cleared by the mid-1950s, however, and new warehouses erected on the site by the early 1960s.[67]

Reflections

The archaeological excavation and associated research of the Salford Twist Mill has thrown new light on the development and physical structure of one of the most significant historic cotton mills in the Manchester manufacturing district. The documentary evidence points to George Lee having been largely responsible for the design of the cast-iron frame for the New Mill rather than it being the work of Boulton & Watt, as stated by Fairbairn in

Figure 13. (a) Fragments of cast-iron beams recovered from the excavation, including examples of the hollow pins retained in the casted clasps, (b) details of the sleeve and clasp with the scar (arrowed) of a Type 1a column head plate on the underside and (c) a near-complete shorter beam with a bolting face at one end and wide sleeve and bolting eye (arrowed) at the opposite end (© University of Salford).

1854. Lee will undoubtedly have drawn on the earlier work of Strutt in Belper and Bage in Shrewsbury and benefited from the advice offered by Boulton & Watt, but should nevertheless be accredited with making a significant contribution to the successful application of cast-iron in the construction of multi-storey buildings.

The beams used in the New Mill display a close resemblance to those used in the Shrewsbury Flax Mill, although a key modification was the addition of small lips to provide a seating for the brick arches, representing the genesis of the inverted T-shaped flanged beam. It is impossible to determine with complete confidence that George Lee was wholly responsible for devising this important detail, although he certainly appears to have been the first to translate the design into practice. Fairbairn asserted that the iron beams in the Salford Twist Mill had been cast with an inverted T-shaped profile, although later researchers threw doubt on this observation, querying how Fairbairn could have gained a complete view of the beams as they were embedded in the brick arches.[68] The archaeological work has vindicated this important detail in Fairbairn's account and has corroborated the width he gave for the bottom flange of the beam, although the thickness of the excavated beams was just 25mm (1in) rather than the 1¼in (31.75mm) stated by Fairbairn.[69]

The archaeological evidence has also shown that the transverse beams were each of four sections, with a bolted connection at the midpoint of the centre aisle and complex joints around the original columns on each side. A slight variation of this design incorporating a clasp, sleeve and column spigot was used in Benyon & Bage's flax mill of 1802–3 on Meadow Lane in Leeds, where the junction of the beam ends embraced the columns and were coupled by a

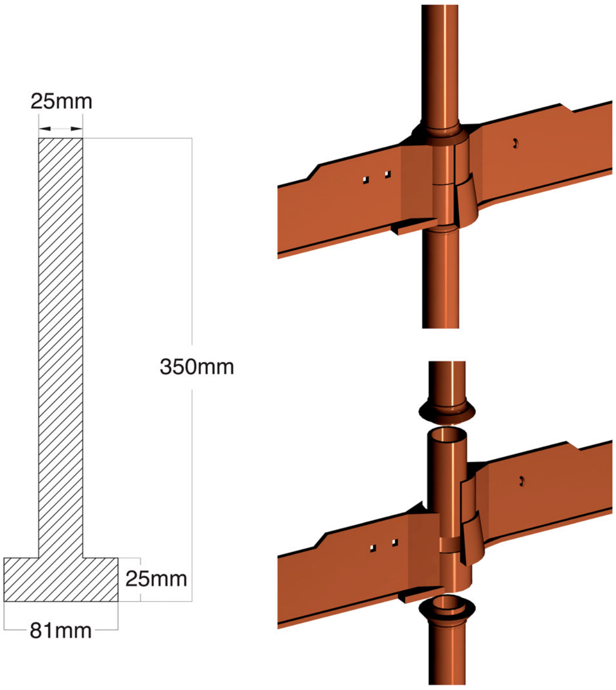

Figure 14. Conjectured detail of the jointing arrangement around the columns and the cross-sectional profile of a beam (© University of Salford).

Figure 16. Fragment of a probable crush box bolted to the base of a column (© University of Salford).

wrought-iron shrink ring.[70] Despite the similarities in other aspects of this mill's iron frame, it is difficult to see how shrink rings will have been fitted around the columns in the New Mill due to a lack of anchor points. It is nevertheless likely that a clamp of some description will have been used to bolster the connection between the beams and columns, perhaps utilising the bolting eye cast onto the vertical face of the beams that spanned the central bay.

Pointing to the use of four 9ft-long sections to each beam, Skempton and Johnson considered the design of Meadow Lane Mill to 'have moved decisively away from the continuous beam which […] were not well adapted to cast iron', although the evidence available suggest that this design improvement had been implemented previously by George Lee in his New Mill to provide a flexible connection at each end of the beams.[71] The divergence of the archaeological evidence from the detail shown in Creighton's drawing hints that the design of the structural frame may have been revised following the column failure in July 1801, and this may have included introducing the inverted T-shaped profile to the beams, which was replicated by Benyon & Bage in their Meadow Lane Mill.[72] It is perhaps significant that the beams used in Meadow Lane Mill were of the same 25mm thickness as those used in the New Mill. The form and detail of the iron beams used in Armley Mill in Leeds, the first woollen mill to utilise 'fireproof' construction, similarly mirror the design

Figure 15. Examples of Type 2 columns showing (a) the foundation pad, (b) the column base and (c) the shaft capped with a head plate (© University of Salford).

Figure 17. (a) Glass bottles and the vestiges of a packing crate discovered within the demolition rubble and (b) examples that had been distorted due to intense heat (© University of Salford).

of those used in the New Mill.[73] Dating to 1804, Armley Mill was erected by Benjamin Gott, who is known to have been a close friend of George Lee, adding weight to a suggestion that the design of the iron frames in this and Meadow Lane Mill were developed from that in Lee's New Mill.

The use of timber roof trusses in the New Mill is unsurprising as cast iron had not been employed for such use at the date of its construction; the roof of the Shrewsbury Flax Mill employs timber members above the narrow barrel-vaulted bays on its upper floor to create a complex multi-pitch transverse roof. Benyon & Bage's Meadow Lane Mill of 1802–3 may have been the first mill to be fitted with a cast-iron frame roof, with the five-storey warehouse of *c.* 1805 at the Salford Twist Mill representing another pioneering example of a 'fireproof' roof structure on a multi-storey building. The use of timber trusses nevertheless appears to have persisted as a common approach in the first generation of 'fireproof' mills, whilst the use of timber queen-post trusses in 19th-century examples of 'fireproof' mills, such as Islington Mill of 1823 in Salford, allowed for a traditional two-pitched roof whilst also creating a useable attic space.

The hollow cylindrical columns employed by George Lee in his New Mill is very likely to have been the first application of this improved type of column in a multi-storey factory. Their dual use as structural support and conduits for steam to heat the mill was certainly a benchmark achievement. Buchanan claimed that the first factory to be heated by steam was Dale & McIntosh's Speyside cotton works in Scotland, which utilised a system installed by

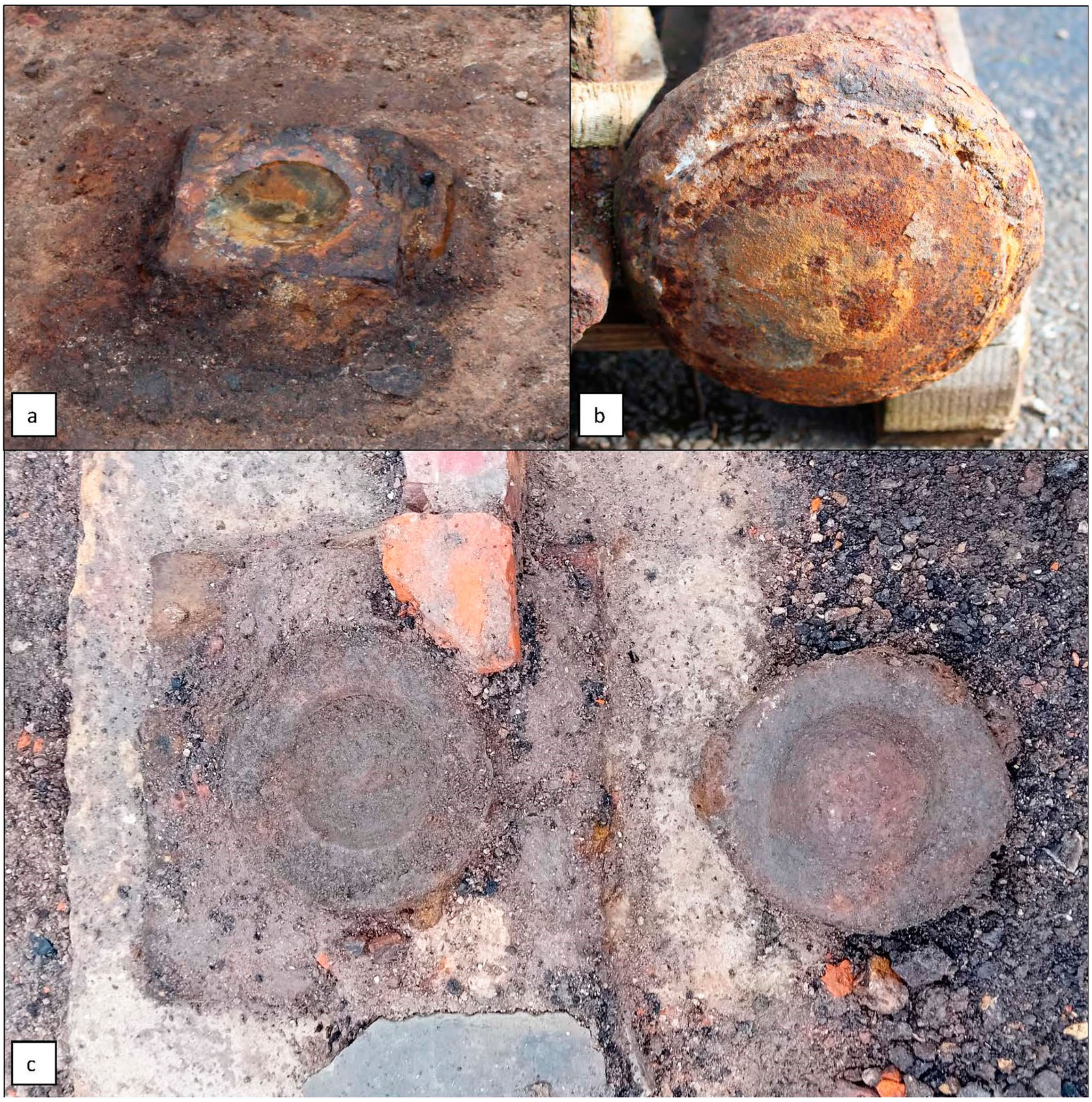

Figure 18. (a) The cupped base for the Type 1 column and (b) the hemispherical column foot used in the New Mill compared with (c) a cupped iron socket set into a stone foundation pad and a hemispherical column foot with collar excavated at Jersey Street Mill (© University of Salford).

a Mr Snodgrass in 1799 but this did not use the structural pillars as heating pipes.[74] The New Mill was undoubtedly the first example of a mill in England to be heated by steam, providing an effective solution that was adopted in numerous steam-powered mills during the early 19th century.

The identification of the Type 1 cast-iron column with its unusual hemispherical foot was another important result from the excavation. Comparable examples were identified in the basement structure of Albion Mill in Manchester, the design of which Fitzgerald attributed to 'a misguided attempt to compensate for movement'.[75] Albion Mill was built in *c.* 1802 by James Newton and William Joynson on land owned in part by George Philips but was reconstructed after a devastating fire in 1816. It is not known whether the columns were salvaged from the original mill or newly supplied for the rebuilt structure, but further examples of columns with a rounded foot were excavated in the Ancoats area of Manchester on the site of Jersey Street Mill, dating to *c.* 1824. These examples had a wide collar to the foot, offering a slight improvement to the Type 1 column in the New Mill but nevertheless demonstrating the longevity of the basic design (Figure 18).

Conclusion

The archaeological excavation and associated research of the Salford Twist Mill has allowed new light to be thrown on the development and physical structure of one of the most significant historic cotton mills in the Manchester manufacturing district, resolving some of the uncertainty debated by previous scholars. The work has also demonstrated the research value of excavating the sites of early steam-powered textile mills archaeologically and using the physical evidence to interrogate the documentary record for the development of individual sites and to test the wider understanding of how the design of multi-storey mills evolved. This aligns with some of the objectives set out in the current historic environment research framework for north-west England, not least an acknowledged need to identify evidence for technological innovation in construction methods applied to industrial buildings.[76] The examination of the fragments of cast-iron beams and columns together with the foundations of the Salford Twist Mill have also highlighted George Lee's significant contribution to textile-mill design and the evolution of iron-framed buildings, and reflects the prowess of Salford as an important early centre of the steam-powered textile industry. This is reflected in the modern townscape by an example of a cast-iron beam salvaged from the excavation and placed on public display on the site of the Salford Twist Mill.

Notes

1. Mike Williams with Douglas A. Farnie, *Cotton Mills in Greater Manchester* (Preston: Carnegie Publishing, 1992), 59–60.
2. Stanley B. Hamilton, 'The Use of Cast Iron in Building', *Transactions of the Newcomen Society* 21 (1941): 139–55; Turpin C. Bannister, 'The First Iron-Framed Buildings', *Architectural Review* 107 (1950): 231–46; Alec Westley Skempton and H.R. Johnson, 'William Strutt's Cotton Mills, 1793–1812', *Newcomen Society* 30 (1960): 179–205; Alec Westley Skempton and H.R. Johnson, 'The First Iron Frames', *Architectural Review* 131 (1962): 175–86; Jennifer Tann, *The Development of the Factory* (London: Cornmarket, 1970); Ron Fitzgerald, 'The Development of the Cast Iron Frame in Textile Mills to 1850', *Industrial Archaeology Review* 10, no. 2 (1988): 127–45, doi.org/10.1179/iar.1988.10.2.127.
3. William Fairbairn, *On The Application of Cast and Wrought Iron to Building Purposes* (London: John Weale, 1854), 3; Sigfried Giedion, *Space, Time and Architecture* (Cambridge: Harvard University Press, 1941); John Gloag and Derek Bridgewater, *A History of Cast Iron in Architecture* (London: Routledge, 1948); Stanley B. Hamilton, 'Old Cast-Iron Structures', *Structural Engineer* 27 (1949): 183.
4. Bannister, 'The First Iron-Framed Buildings', 231–46.
5. *Ibid*., 239–40.
6. Tann, *The Development of the Factory*, 136.
7. John Yates, 'The Three Ages of the Ditherington Flax Mill: The Rolt Memorial Lecture 2016', *Industrial Archaeology Review* 38, no. 2 (2016): 85, doi.org/10.1080/03090728.2016.1252156; Colum Giles and Mike Williams, eds, *Ditherington Mill and the Industrial Revolution* (Swindon: Historic England, 2015).
8. Skempton and Johnson, 'The First Iron Frames', 181–2.
9. Tann, *The Development of the Factory*, 137–9.
10. Tony Bonson, 'The First Iron-Framed Building?', *Industrial Archaeology Review* 22, no. 1 (2000): 63–6, doi.org/10.1179/iar.2000.22.1.63.
11. Details results obtained from the excavation are set out in Graham Mottershead *et al*., 'Archaeological Excavation Final Report: Chapel Wharf, Salford, Greater Manchester' (Salford Archaeology Report No. SA/2022/83, 2022), OASIS No. 521301.
12. Peter Maw, 'Provincial Merchants in Eighteenth-Century England: The "Great Oaks" of Manchester', *English Historical Review* 136, no. 580 (2021): 599–600, doi.org/10.1093/ehr/ceab156.
13. Chris Aspin, *The Water-Spinners: A New Look at the Early Cotton Trade* (Helmshore: Helmshore Local History Society, 2003), 124.
14. Edward Baines, *History of the Cotton Manufacturer in Great Britain* (London: Fisher, Fisher and Jackson, 1835), 149–50.
15. Stanley David Chapman, 'Fixed Capital Formation in the British Cotton Industry 1770–1815', *Economic History Review*, New Series 23 (1970): 235–66.
16. Mike Williams with Douglas Antony Farnie, *Cotton Mills in Greater Manchester* (Preston: Carnegie, 1992), 51.
17. Steve Little, 'The Growth of Manchester and its Textile Industry', in Ian Miller and Chris Wild, *A & G Murray and the Cotton Mills of Ancoats*, (Lancaster: Oxford Archaeology North, 2007), 7–24.
18. Victor Innes Tomlinson, 'The Coming of Industry', in *Salford: A City and its Past*, ed. Tom Bergin, Dorothy N. Pearce and Stanley Shaw (Salford: City of Salford Cultural Services Department, 1975), 18. The evidence for the waterwheel is not given.
19. *Manchester Courier and Lancashire General Advertiser*, December 14, 1844.
20. Boulton & Watt Collection MS 3147/5/63, Peter Atherton of Liverpool and Charles Wood, John Philips and George Philips of Manchester, May 2, 1791.
21. Boulton & Watt Collection MS 3147/2/10/42, Peter Atherton/Salford Twist Co, Salford, No. 1, February–June 1791, August 1813.
22. Boulton & Watt Collection MS 3147/3/249/48, Peter Ewart to John Southern, August 18, 1792.
23. *The Annual Biography and Obituary for the Year 1827* 11 (London: Longman, Rees, Orme, Brown and Green, 1827), 245.
24. Ian Miller and John Glithero, 'Richard Arkwright's Shudehill Mill: The Archaeology of Manchester's First Steam-powered Cotton Mill', *Industrial Archaeology Review* 38, no. 2 (2016): 99, doi.org/10.1080/03090728.2016.1266214.
25. Robert Owen, *The Life of Robert Owen Written by Himself* (London: Effingham Wilson, 1857), 26–7.
26. Andrew Ure, *The Cotton Manufacture of Great Britain*, 1 (London: Charles Knight, 1836), 274; Ian Miller, Chris Wild and Richard Gregory, *Piccadilly Place: Uncovering Manchester's Industrial Origins* (Lancaster: Oxford Archaeology, 2007).
27. Robert Owen, *The Life of Robert Owen Written by Himself* (London: Effingham Wilson, 1857), 26.
28. Boulton & Watt Collection MS 3219/6/1/1/2/11/93, Letter. George Lee to James Watt junior, October 20, 1790.
29. Boulton & Watt Collection MS 3219/6/1/1/2/11/94, Letter. George Lee to James Watt junior, May 27, 1791.
30. *Manchester Mercury*, March 18, 1794.
31. Ian Miller and Chris Wild, *A & G Murray and the Cotton Mills of Ancoats* (Lancaster: Oxford Archaeology, 2007), 63–4.
32. Richard L. Hills, *Development of Power in the Textile Industry from 1700–1930* (Ashbourne: Landmark, 2008), 64.
33. Quoted in Tann, *The Development of the Factory*, 31.
34. Boulton & Watt Collection MS 3147/5/242/a, Salford Twist Co, Salford, No. 2, 1795, 1798, 1799, 1803.
35. Boulton & Watt Collection MS 3147/3/415/33, Letter from George Lee to James Watt junior, March 10, 1798.
36. Arnold J. Pacey, 'Earliest Cast-Iron Beams', *Architectural Review* 145 (1969): 1696–7.
37. Boulton & Watt Collection MS 3219/6/1/1/2/11, Letters to James Watt junior from various correspondents with a surname beginning in L.
38. Boulton & Watt Collection MS 3219/6/1/1/2/11/112, Letter. George Lee to James Watt junior, July 16, 1800.
39. Quoted in Tann, *The Development of the Factory*, 111.
40. Keith A. Falconer, 'Fireproof Mills – The Widening Perspectives', *Industrial Archaeology Review* 16, no. 1 (1993): 20, doi.org/10.1179/iar.1993.16.1.11.
41. Quoted in Tann, *The Development of the Factory*, 143.
42. Robertson Buchanan, *An Essay on the Warming of Mills and Other Buildings by Steam* (Glasgow: W. Lang, 1807), 21.
43. Miller and Glithero, 'Richard Arkwright's Shudehill Mill', 107.
44. Boulton & Watt Collection MS 3147/5/242/c, Salford Twist Co (Philips, Wood & Lee), 1800–4.
45. Hills, *Development of Power in the Textile Industry from 1700–1930*, 64–6.
46. *Manchester Courier and Lancashire General Advertiser*, May 13, 1843.
47. John Scholes, *Scholes' Manchester and Salford Directory*, 2nd edn (Manchester: Sowler and Russell, 1797), 76.
48. John Charles Griffiths, *The Third Man: The Life and Times of William Murdoch, 1754–1839* (London: Andre Deutsch, 1992), 240–4.
49. Plan and section drawings of the New Mill and the Old Mill prepared by Boulton & Watt in September 1805 and June 1806 respectively when

designing the gas plant are reproduced in Tann, *The Development of the Factory*, 21 and 124.
50. Samuel Clegg, *A Practical Treatise on the Manufacture and Distribution of Coal-Gas*, 2nd edn (London: John Weale, 1853), 12.
51. Parliamentary Paper PP 1809 (220), Select Committee on Gas-Light and Coke Company's Bill to incorporate Persons for procuring Coke, Oil, Tar Pitch, Ammoniacal Liquor and Inflammable Air from Coal: Minutes of Evidence, 42.
52. A comprehensive account of the gas plant at the Salford Twist Mill, set in its context of the development of gas lighting, is set out in Ian Edward West, 'Light Satanic Mills – The Impact of Artificial Lighting in Early Factories' (PhD thesis, University of Leicester, 2008), https://hdl.handle.net/2381/7721.
53. Roger Lloyd-Jones and A.A. Le Roux, 'The Size of Firms in the Cotton Industry: Manchester, 1815–41', *Economic History Review* 33 (1980): 81.
54. *Liverpool Mercury*, August 11, 1826.
55. *London Gazette*, March 25, 1831.
56. *Manchester Courier and Lancashire General Advertiser*, December 14, 1844.
57. *Manchester Courier and Lancashire General Advertiser*, June 5, 1841; *London Gazette*, January 24, 1843.
58. *Manchester Courier and Lancashire General Advertiser*, May 13, 1843.
59. *Manchester Courier and Lancashire General Advertiser*, June 10, 1843.
60. *Leicester Chronicle*, July 8, 1843.
61. *Manchester Courier and Lancashire General Advertiser*, 26 October 1844; *Manchester Courier and Lancashire General Advertiser*, December 14, 1844.
62. *Chester Chronicle*, February 28, 1845.
63. 'Fall of Part of the Iron Roof of a Warehouse', *The Builder* 3 (1845): 119.
64. 'The Fall of a Warehouse in Salford – Further Litigation', *Manchester Courier and Lancashire General Advertiser*, January 28, 1884.
65. Bannister, 'The First Iron-Framed Buildings', 242; Fitzgerald, 'The Development of the Cast Iron Frame in Textile Mills to 1850', 129.
66. Bannister, 'The First Iron-Framed Buildings', 242.
67. National Grid 1:1250 map SJ8398NW, 1962.
68. Pacey, 'Earliest Cast-Iron Beams', 1696–7; Tann, *The Development of the Factory*, 143.
69. Fairbairn, *On The Application of Cast and Wrought Iron to Building Purposes*, 3.
70. Fitzgerald, 'The Development of the Cast Iron Frame in Textile Mills to 1850', 131.
71. Skempton and Johnson, 'The First Iron Frames', 185.
72. Fitzgerald, 'The Development of the Cast Iron Frame in Textile Mills to 1850', 129–30.
73. Fitzgerald, 'The Development of the Cast Iron Frame in Textile Mills to 1850', 131–2.
74. Buchanan, *An Essay on the Warming of Mills and Other Buildings by Steam*, 8.
75. Ron Fitzgerald, 'Albion Mill, Manchester', *Industrial Archaeology Review* 10, no. 2 (1988): 220–1, doi.org/10.1179/iar.1988.10.2.204.
76. Michael Nevell and Norman Redhead, eds, *The Historic Environment of North West England: A Resource Assessment and Research Framework* (Salford: University of Salford, 2023), 245–6.

Acknowledgements

The excavation of the Salford Twist Mill was funded by Dandara Ltd and was carried out under the direction and management of Graham Mottershead and Ian Miller of Salford Archaeology within the University of Salford. The author is especially grateful to Chris Wild for his invaluable input in recording and interpreting the cast-iron components and to Richard Ker for producing the illustrations. Thanks are also expressed to Oliver Cook of Salford Archaeology for providing information from the excavation of Jersey Street Mill.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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