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TONE WORKS, WELLINGTON, SOMERSET
SURVEY AND ANALYSIS OF BUILDINGS, POWER SYSTEMS AND MACHINERY

VOLUME ONE: REPORT

Mike Williams

ARCHITECTURAL INVESTIGATION

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VOLUME 1: REPORT

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At English Heritage Dr Lucy Jessop carried out extensive documentary research and wrote the Appendices. On-site and archive photography was by Peter Williams and James O. Davies. The survey drawings were produced by Nigel Fradgley and Mike Williams. The draft text was read by Barry Jones and Dr Agnieszka Sadraei. The images were scanned and the report desk-top published by Ursula Dugard-Craig.

INTRODUCTION

Tone Works is the historic cloth finishing and dye works of Fox Brothers and Company of Wellington. Located on the River Tone about a mile north of the town, it comprises a large and well-preserved complex of one and two-storeyed buildings, ponds and watercourses, ranging in date from the early 19th century to the early 20th century. Parts of the site have become dilapidated in recent years, but it still retains an unusual variety of historic industrial buildings and is now the most intact textile finishing works in the South West. It includes well-preserved examples of building types and detailed features which have suffered widespread demolition elsewhere. Of particular note is the remarkable survival, in nearly-working condition, of the full complement of finishing and dyeing machinery. This is probably the last complete set of historic cloth finishing machinery in the country. Of additional importance is the unusually well-preserved evidence of the development of power systems. This includes an intact system of late 19th century line shafting (one of only two that are known to survive in a textile mill), well-preserved mechanical and architectural evidence of the water and steam-power systems, and the survival, virtually intact, of most of an early DC electric power system. In the early 20th century the site combined the use of all three types of power. The machinery was preserved because Fox Brothers increasingly specialised in the manufacture of high-quality woollen cloths that could only be produced using traditional methods, some of which were developed by the company at the site (Figure 1).

Figure 1.
Partly-finished cloth left in a scouring machine, Tone Works, July 2007. [DP043821]

The close association of Tone Works with Fox Brothers adds to its historical significance. Fox Brothers was one of the most successful and long-lived firms in the history of the South-West textile industry, and is still based in Wellington. The family business was formed in the late 18th century but had origins in the earlier pre-factory textile industry in Somerset. It was based at Tonedale Mills, a huge integrated spinning and weaving complex located just south of Tone Works. During the 19th century the firm expanded and developed an unusually wide range of products, including both woollen and worsted cloths. Government contacts provided an increasingly important source of orders, for both military and overseas departments. Fox Brothers operated as a fully-integrated firm which maintained full control of all the stages of production. The technical complexity of the business is now reflected in the scale and diversity of the building types at the two sites.

The availability of an extensive archive of Fox Brothers and Company documents has provided new details on the history of the firm and enabled more accurate dating of buildings and machinery. Access to the archive, which is still privately owned, was kindly provided by Jack Hudson, current MD of Fox Brothers, and Michael Fox. The archive is of great historic value, comprising a detailed record of business activities at all the Fox sites from the late 18th century. It includes original documents and memoranda, journals and books written by members of the Fox family.

Tone Works was first inspected and photographed by RCHME in 1995, when it was still operational, and an initial report was written in 2000. The present report was prepared at the request of the English Heritage South West Region to inform an application for redevelopment. Its aim is to present a comprehensive interpretation of the whole site, including the identification and assessment of all surviving historic buildings, machinery, power systems and related landscape features. It is based on recent on-site fieldwork combined with documentary research; a significant constraint has been the inaccessibility of parts of the site due to asbestos contamination, notably the Dye Works. Descriptions of these areas are based on information gathered in 1995.

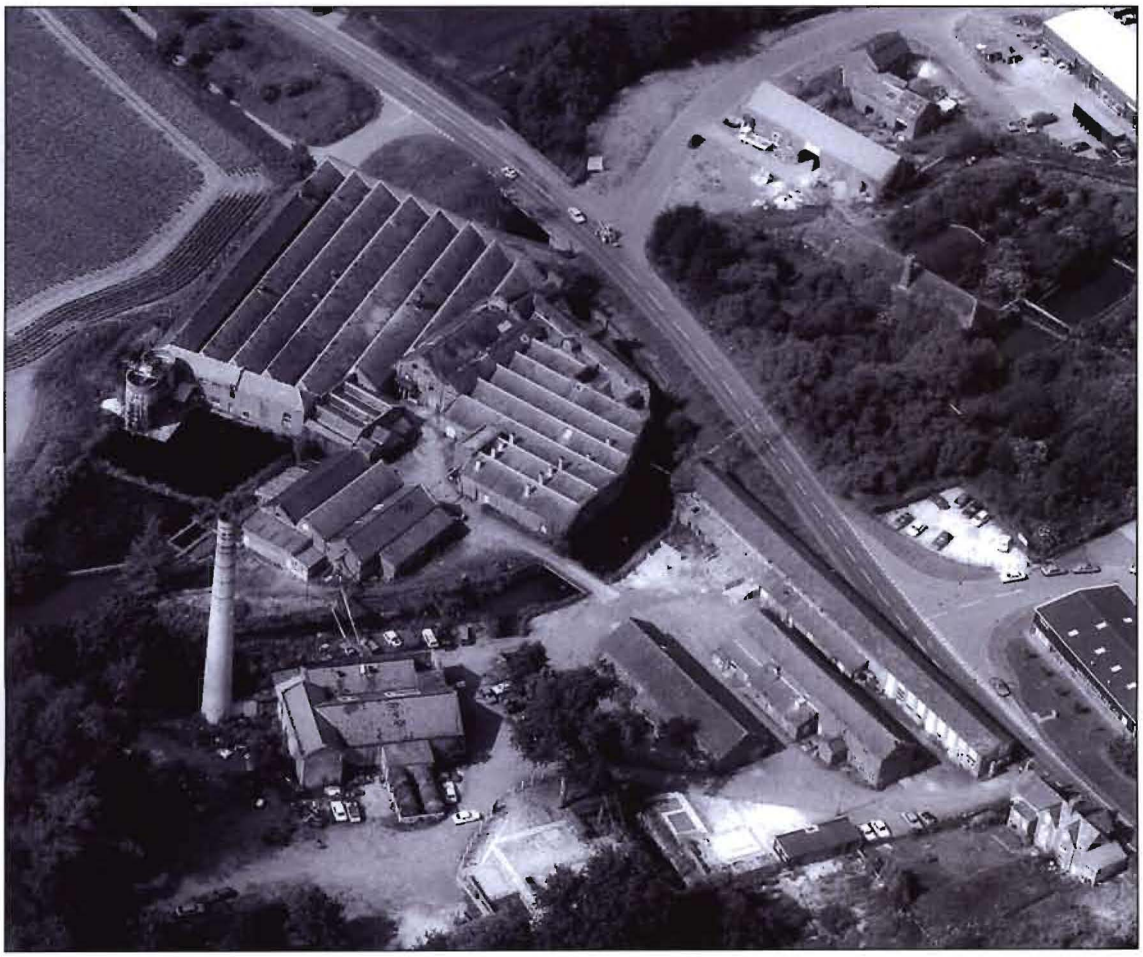


Figure 2.
Tone Works in 1995. [NBR 4831150]

HISTORICAL BACKGROUND

Introduction to the history of Fox Brothers and Company.

Fox Brothers and Company was founded by the Quaker merchant and industrial pioneer Thomas Fox, who began his career in 1768 working for his maternal grandfather Thomas Were (see Appendix 1). The Were family were successful manufacturers of woollen and worsted cloths, principally serges[1], who occupied a fulling mill on the site of Tone Works. Their clothier business had probably been based in the Wellington area from at least the Elizabethan period.[2] When Thomas Fox joined the firm it was still organised along traditional lines, with most stages of cloth production 'put-out' from a central warehouse to cottage-based spinners and weavers. This was typical of the pre-factory textile industry in Somerset and neighbouring parts of Devon, which had grown to national importance in the 17th century but was in decline by the late 18th century. Thomas Fox transformed the Weres' clothier business into a factory-based firm on a scale which could compete with the new textile industries emerging in other areas of England. He initially managed the firm with several other members of the Were family but was left as the sole proprietor in 1796, after which the business continued under the Fox family name.

Evidence from both the company's archives and the extant buildings themselves provides insights into how Thomas Fox created one of the largest and longest-surviving family firms in the English textile industry. In contrast to the traditional methods of the Were family, Fox fully embraced the potential of the developing factory system with the construction of yarn-spinning mills at Tonedale and Coldharbour and a cloth-finishing works at Tone. All three sites originated as small water-powered mills that were rebuilt or extended as new factories. This scale of investment in early factory methods was comparable with that of the largest firms in Wiltshire, Gloucestershire and the northern textile areas. A distinctive feature of the Fox company, however, was its unusually wide range of products, a characteristic which was to be significant in the firm's long-term survival (Figure 3). One example was the introduction by Thomas Fox of processes for the manufacture and finishing of new types of fine woollen cloths while maintaining production of the more traditional cloths. The development of improved methods for cloth finishing gave Fox Brothers an international

Figure 3.
Labels from a variety of Fox Brothers' products.
[AA96/03914]

reputation for the production of high quality fine woollen flannels that was maintained into the 21st century. This willingness to diversify contrasted with the textile industry as a whole: in the 19th century firms increasingly specialised in a narrower range of processes and products in order to maximise output.

As the company expanded in the 19th century it continued to be involved in all stages of the production of wool and worsted cloths, but factory methods enabled far greater control of manufacturing processes than was possible under the old system of out-working. This was reflected in the development of the factory sites, which acquired a notably wide range of building types, each functionally designed for particular processes. The integration of textile processes was developed to an unprecedented level at the Fox sites. Tonedale Mills grew into the largest mill complex in the South-West, but the company also expanded far beyond Wellington. Its dominant position in the industry led to the takeover of several other textile firms in the late 19th and early 20th century, notably Bliss Tweed Mill in Oxfordshire, while in the First World War around 30 firms in the Yorkshire textile industry were placed under Fox Brothers' management.[3]

The range of products included several cloth types for which Fox Brothers were particularly well known. These included the fine woollen flannels, mentioned above, that required a particular combination of finishing processes at Tone Works. The firm also became noted dyers, specialising in dark blue indigo-dyed cloths but also producing a wide range of other colours and tints. The size of the firm and its technical expertise probably contributed to its success in winning large contracts with Government departments, both in Britain and abroad. Tonedale Mills repeatedly expanded as a result of the demand for cloth for military uniforms. A notable development to this side of the business was the introduction of a Government-approved formula for khaki dye in the late 19th century, for which Fox Brothers acquired sole manufacturing rights (see Appendix 2). Fox's dye became the standard khaki for British uniforms. In the early 20th century the firm also introduced a patented type of puttee, for which they developed special narrow-weaving and finishing processes. 'Fox's Improved Puttees' were highly successful for both military and civilian use, being produced in huge quantities in new buildings at Tonedale and Tone Works (Figure 4; see Appendix 2).

Figure 4.
Disused equipment used for moulding Fox's Patented Improved Puttees, photographed at Tonedale in 1995.[AA96/03915]

The 20th-century history of Fox Brothers was in part a reflection of the changing fortunes of the traditional textile industry in Britain, although it out-lived the vast majority of firms in other areas. The company weathered the gradual decline of the industry by increasingly specialising in its high-quality traditional products, with the result that machinery, fixed plant and buildings were all still remarkably well-preserved in the mid-1990s.

The development of Tone Works

Tone Works was Fox Brothers' original mill site and has an exceptionally long history of continuous use for cloth finishing. In the mid-18th century Tone (in the early documents it is simply referred to as 'Tone') was a water-powered fulling mill used for finishing the cloth produced by the Weres' network of handloom weavers. No extant structures from this period have been found, but documentary evidence indicates that the mill was maintained and occasionally rebuilt. Under the later management of Thomas Fox and his descendents Tone was developed as the main dyeing and finishing site for all the company's mills. The introduction of improved finishing and dyeing methods was central to the long-term success of Fox Brothers. The site remained in use for traditional methods of cloth finishing until Fox Brothers moved to temporary accommodation in a nearby modern factory unit in 2000. The following account is partly based on recent research into original documents in the Fox Company archive (see Appendix 2).

The site before 1800

The Were family were in occupation of a fulling mill on the site of Tone Works by 1750. Documents recorded in Thomas Fox's memorandum book include leases and conveyances related to the Tone property in 1750, 1760 and 1777. The site finally passed to Fox when he became the last surviving partner of the Were company in 1796.[4]

The Fox archive contains several references to an 18th century mill at Tone, and suggests that it may have been rebuilt during the 1750s and 1760s, although its exact site is not recorded. The archive confirms that the Were company occupied the site in the period indicated by the date stone, now reset in a late 19th-century gable on the Dye Works, which reads: 'Thomas & Elizath Were and Sons 1754'. A document of 1752 refers to the head of water at the site (about 3 feet – significantly less than that in the extant wheel chamber) and lists timbers for building or repairing a mill wheel, while another of 1759 lists more timber for the wheel.[5] An account of 1765 lists timbers wanted 'for our New fulling Mill at Tone Bridge', including parts of the wheel and large quantities of timber for the 'sistern' (presumably a launder) and the water courses.[6] Thomas Were's will of 1773 includes a 'new erected house and Fulling Mills' at Runnington (Tone Works straddles the Parishes of Wellington and Runnington).[7] In 1782, the Tone site consisted of 'Fulling Mills, Burling shop, Mill House, Dwelling House – under one roof, brick and tile', valued at £500.[8] This description suggests that the site then comprised a long building with the fulling mill at one end and dwelling house at the other, a typical layout for a small grist or fulling mill. Comparison with the later Tithe Maps (see below) suggests that the most likely position for this mill was on a leat close to the site of the extant wheel chamber.[9] The 'burling shop' would have been a workshop used for the inspection and cleaning of the finished

cloth. Were and Co. also constructed a fulling mill at Uffculme in 1766 (on the site of a paper mill), thus increasing the business's fulling capacity further.[10]

Tone Works in the early 19th century

Fewer documentary references have been found concerning the early 19th century, although it is known that the site underwent considerable development in this period. One of the two extant dry houses and a gig mill had been added by 1818, when a fire insurance policy mentioned a 'water fulling mill house', the 'water wheel, going gear & gig mill', and the 'drying house'.[11] The site also included a dwelling house and three cottages. It is not clear from this if the gig mill was a separate building or a machine in an existing building, but this combination of features indicates that the mill had been extended to form a powered cloth finishing works before 1820.

The Tithe Maps for Wellington and Runnington give a fairly accurate picture of the site in 1839 and indicate that it had expanded further, either adding to or replacing the late 18th-century mill (Figures 5 and 6). They also show how the original course of the River Tone influenced the layout of the site. The river followed a sharp U-bend to the west of the road, enclosing a narrow level area which was crossed by the mill race. Most of the mill buildings were built on the south side of the race, and their layout was therefore constrained by the river. Following a series of floods in the late 19th century the river was straightened and the western half of this U-bend was removed (see below). The race was also rebuilt in the early 19th century to suit the new layout. The Tithe Maps show it following an indirect course around the west and north sides of the extended mill, where it entered an attached rectangular structure, presumably a wheel house. This is similar to the site and proportions of the extant wheel chamber. The Tithe Maps also show a large pond associated with the mill to the west, which is partially extant. In 1839 at least five buildings adjoined the south side of the wheel house, overlapping with the northern end of the extant Dye Works. The site had also acquired a second Dry House, and two more small buildings flanked the entrance from the road. Apart from the wheel

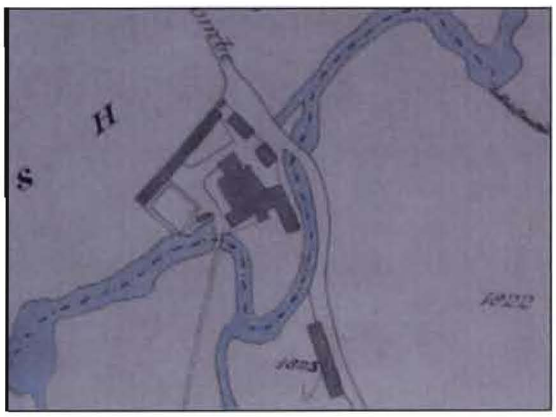


Figure 5.
Extract from Wellington Tithe Map, 1839.
[SARS D/D/RT/367; original held at the Somerset Record Office. Used with permission]

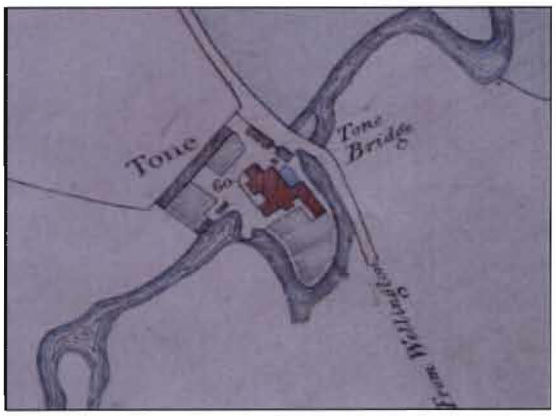


Figure 6.
Extract from Runnington Tithe Map, 1839.
[SARS D/D/RT/43; original held at the Somerset Record Office. Used with permission]

chamber and the two dry houses, most of these buildings are not extant. Their foundations appear to have been used in later rebuilding, however, and parts of the early 19th-century walls may survive in the Dye Works. The only available description of the site in this period is given by a fire insurance policy of 1846, which listed the 'Tone Fulling Mill with Ware room over – Dwelling House Burling Shops & Dye House'; the buildings were valued at £700 and the machines and stock at £1100.[12] This is the earliest reference to a separate dye house at Tone.

Development in the mid- and late 19th century

Fox Brothers invested heavily in machinery and processes between the 1860s and the 1890s, resulting in numerous alterations to the site, several phases of new building and the removal of many of the earlier structures. The First Edition 1:2,500 plan shows the extent of the site before the addition of the new Finishing Works in the 1890s (Figure 7). In keeping with the earlier development of the firm, however, existing machinery and buildings were not completely replaced, and traditional

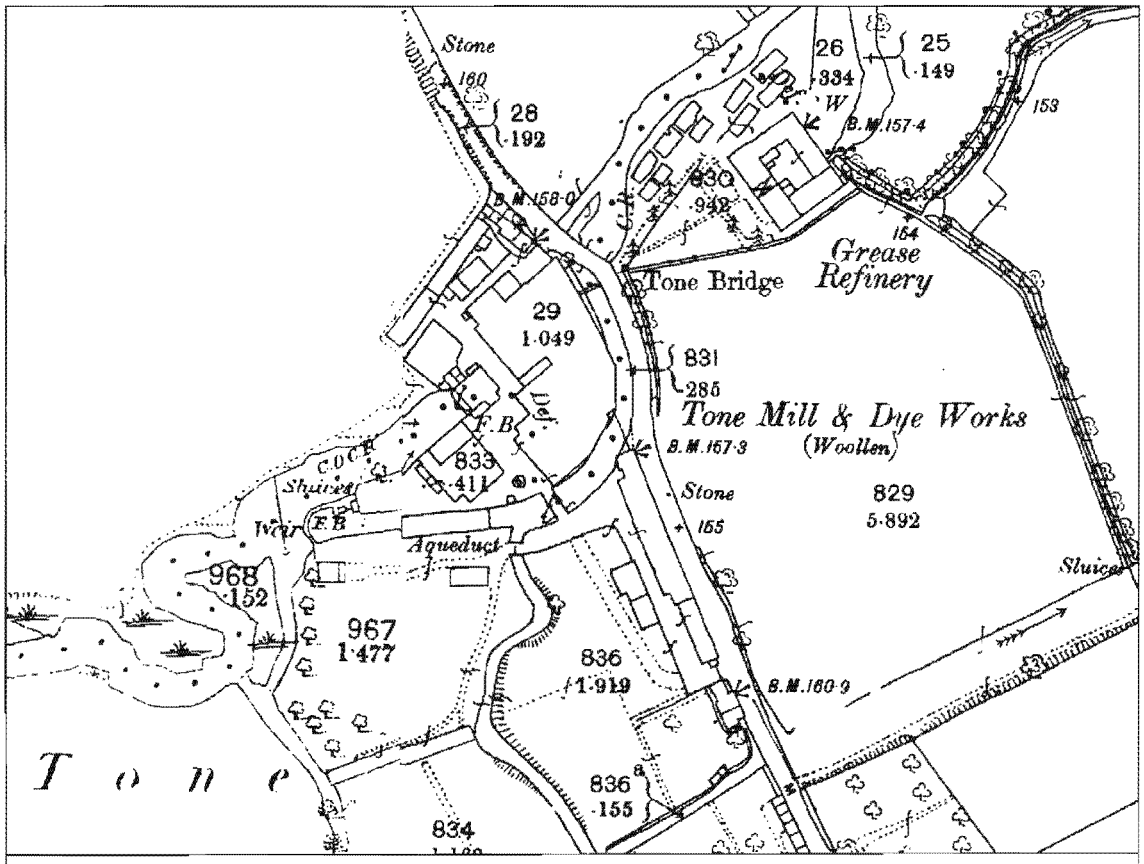


Figure 7.
Extract from O.S. 1:2,500 plans showing Tone Works.
[Sheet 78/3, surveyed 1888, published 1889, and Sheet 78/4, surveyed 1886-7, published 1890]

methods were retained alongside the new machines. Alterations included reorganising manufacturing processes into segregated areas for dyeing and finishing and the addition of at least two new steam-power systems to the earlier water-power system. The expansion of the site was closely linked with the development of its water-management system, including facilities for the treatment and distribution of softened process water. Towards the end of the 19th century buildings were added for the treatment of chemical waste, eventually leading to the construction of an extensive Grease Works to the east of the site (not covered in this report).

The development of the water-management system

The supply of large quantities of river water for both power and processes was critical to the efficient operation of Tone Works and was greatly improved in this period, leading to extensive alterations to the surrounding landscape and influencing the expansion of the site (Figure 8). Engineering works included changing the course of the river, probably in 1871 and 1884, to help alleviate flooding and provide a new area of reclaimed land for building.[13] The western half of the U-bend in the river, shown on the Tithe Maps, was filled in and replaced by the weir and a new section of straight channel, which survives today. The OS plans of 1889 indicates that part of the old river channel was temporarily retained to form a leat feeding the headrace, with the newly-built stretch of the main river serving as a bypass, and that new buildings had already been built on the reclaimed area. A curved weir was built across the upstream end of the new river channel, at the head of the leat.[14] A bypass sluice was built in the side of the leat just below the weir so that flood waters could be diverted into the main river. The 1871 work also included construction of a bridge across the new section of the river, sited close to the confluence with the Back Stream flowing into the site from Tonedale Mills.

The ponds to the west of the Finishing Works date from 1892-3 (Figure 8).[15] The present form of the leat was created by straightening the remaining part of the old river channel with brick retaining walls. Immediately north of the leat the new ponds were excavated and enclosed by additional walls. Material excavated from the ponds may have been used for raising the floor level of the new Finishing Shed, which was being built at this time (see below). The ponds were used to maintain an adequate supply of softened water for use in the finishing

Figure 8.
The system of ponds, sluices and water treatment facilities had a major influence on the development of Tone Works. [AA96/00691]

works, and were associated with the purchase of a water-softening plant in 1898 and the addition of two water-softening towers to the north-east corner of the ponds in 1914.[16] They were subdivided into separate areas for hard and soft water by a central low wall, which is shown in illustrations of the 1920s and later. The hard water pond was to the west (upstream); it was filled from the river except in times of flood, when cleaner water was obtained from the old pond to the west of the site.[17]

The firm also had to deal with the high levels of water pollution created by cloth finishing and dyeing (see Appendix 2). The contaminated water from the scouring machines was treated in a grease works by adding acid, converting the soapy effluent into a lanolin grease which had a commercial value. Solid contaminants were removed using a system of filtration tanks. Waste material was originally simply spread onto the surrounding meadows, but by the 1870s a grease works was located close to the main site.[18] This was replaced by the new boiler house added in 1884 (see below). The new larger Grease Works was built from 1882 across the road to the east of the site; after Fox brothers lost a major legal case concerning their pollution of the river in 1893, this was greatly enlarged, with two rows of filter tanks alongside the river by the 1920s.[19]

Building development up to c1890

The late 19th century saw extensive redevelopment of Tone Works, including several phases of new building, alterations and demolition. An engraving on a letter heading probably shows the site in c1886-7, shortly before the construction of the new Finishing Shed (see below).[20] The engraving shows the earlier buildings adjoining the wheel chamber and some of the late 19th-century extensions; parts of the earlier buildings were later rebuilt into the present form of the Dye Works, whilst others were demolished in the 1890s during the construction of the Finishing Shed (Figure 9). In c1886

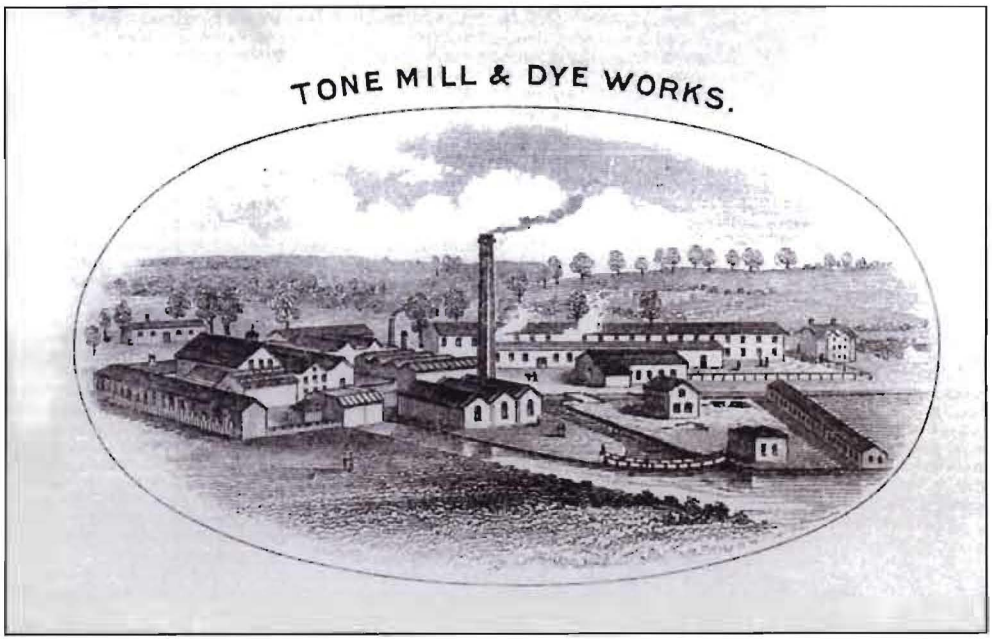


Figure 9.
Tone Works in c1886, taken from the heading of a letter dated 1892. [SARS A\BBN/2/2]

the buildings adjoining the wheel chamber included a two-and-a-half-storeyed wide-gabled building with a cupola and another two-storeyed M-roofed building attached to its south. The gables of these two buildings appear to have been mimicked in the gables of the late 19th-century buildings which now overlook the yard. Other late 19th-century extensions to the south eventually completely filled in the narrow area enclosed by the river.

The site has always been prone to flooding, and this occasionally influenced new building works. F. H. Fox reported a particularly disastrous flood in the year 1888-89, 'when half the width of the main road was washed away down to the river-bed. The Works were isolated for a time as the water was some three feet deep. There was a dreadful mess to clear up afterwards'.[21]

The most common additions up to 1890 were extensions to the dye works. Dye Works buildings were built or extended in 1868, 1869, 1871 and 1874[22], with another substantial addition in 1884-5[23], a clear indication of the growing importance of dyeing to Fox Brothers in this period. The new buildings are shown on the 1886 letter heading, although some of their roof details differ from the extant structures, suggesting that they were later rebuilt or re-roofed. They comprised two main buildings, a north-light shed of four bays with a longer and slightly taller gabled building adjoining to the east. Both were built to respect the original course of the river, suggesting that they could have been added before the river was altered in 1871 or 1884. Comparison with the Tithe Map suggests that the taller east building may have been an extension of a similar-shaped building that was extant in 1839.

Additions were also made to the buildings used for finishing in this period, including a 'new shed for washers' (presumably scouring) in 1880.[24] References to purchases of machinery indicate the range of processes in the new buildings (see Appendix 2, Tone Works Machinery). Fulling stocks were still in use in 1881, and were retained after a repair of that year. Fourteen of the more efficient milling machines were bought in 1887, with more bought each year thereafter. The fulling stocks were probably located in the earlier part of the site close to the wheel chamber, and may not have been removed until the construction of the new Finishing Shed in 1893. In spite of the references to new dye works buildings, and the firm's reputation as dyers of indigo cloths in particular, fewer records survive of the purchase of dyeing machinery. The dye vats and related machinery may not have been of high intrinsic value or may have been largely made in-house. One reference from 1877 mentions the installation of 'new vat no. 4' at Tone Works.[25] Financial records from the 1870s and 80s indicate the continuously high value of the dyestuffs that were stored at Tone Works.[26] Other new buildings related to cloth finishing included an extension to a Dry House in 1868 (presumably the South Dry House – see Description), a new Burling House in 1871, a new Racking Shed in 1878 and a White Room in 1888.[27] The Racking Shed was probably the long single-storeyed dry house shown on the 1886 letter heading, located to the south-west of the site. The White Room was a segregated area for the dyeing and finishing of white cloths, for which it was important to avoid contamination from other colours. This may have been a building added to the south of the river in this period, which was used for whites in the early 20th century (building 4 on the Block Plan, Figure 10).[28]

Steam for power and processes

Steam was required both for engines and to provide large quantities of heated water for processes. There is no documentary evidence of boilers at the site in the early 19th century, and the first

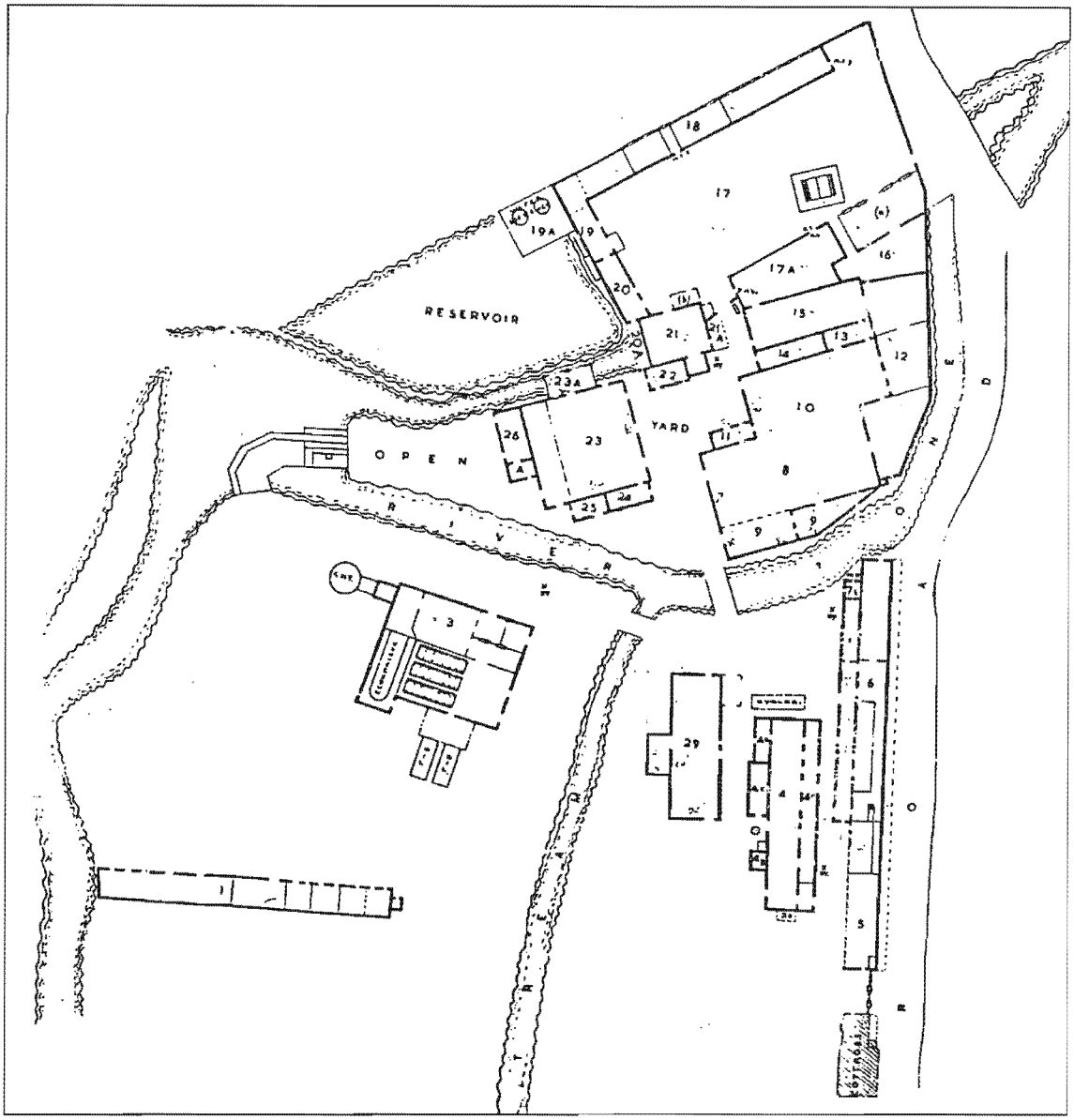


Figure 10.
Undated Block Plan of Tone Works, showing the site in the mid-20th century. [Fox Brothers & Co archive]

boilers may have been associated with the introduction of separate Dye Works buildings from the 1840s. In 1863 two boilers were in use at the Tone Dye House.[29] The first available reference to steam power is to an engine valued at £500 in 1880, and by 1882 the site had five boilers of different dates.[30] Some of these boilers were obtained second-hand from Tonedale, and it seems likely that some were used for processes and others for the engine. The 1880s boilers were located close to the Dye Works, and were replaced when the works were extended.[31]

The detached Boiler House which still overlooks the west side of the yard replaced the earlier Dye Works boilers and was a significant addition to the site, representing a major reorganisation of the whole steam-power system. It was built in 1883-4 on land reclaimed after the alterations to the

river, and was described as 'working splendidly' with a new economiser in 1885.[32] The new boiler house served as a centralised steam plant for the enlarged site, providing steam for engines and hot water for the scouring and dyeing. It is shown on the 1892 letter heading with a triple-span roof and a nearby free-standing chimney. The chimney may have pre-dated the Boiler House itself, since an earlier boiler, chimney and economiser were built in 1871.[33] The chimney had been demolished by 1930, by which time process steam was supplied from the boilers of the new Power House across the river (see below).[34]

The new Finishing Works

In the 1890s the development of processes and machinery continued with the reorganisation of scouring, milling and related processes into a newly-built north-light shed. The shed was the largest structure on the site and incorporated the latest principles of factory design, with its own steam- and water-power systems, process-water management system and an efficient internal layout of machinery. It was functionally linked to other recent additions and was the culmination of an ongoing overhaul of Tone Works that had begun a decade earlier, including the new steam plant, ponds, water-softening plant and the extension of the Dye Works to the south. It occupied the area between the rebuilt Dye Works and the North Dry House, replacing several earlier buildings. F. H. Fox described the new mill house, built on raised ground to minimize future flooding, as 'covering the old yard and roadway and the site of two cottages... the machinery had to be moved into it without stopping production'.[35] Most of the wheel chamber was retained beneath the new shed roof, but the adjoining buildings shown in the c1886 letter head, and any surviving early 19th-century buildings, were demolished. The North Dry House was retained and supported the new shed's main drive shaft, but its west end was rebuilt to include a large tank for softened water (see Description and Analysis of Buildings).

The new building, which remained in use until the company ceased working at Tone in 2000, cost the considerable sum of £5428:11:02 between 1893 and 1895.[36] The shed was equipped with the latest machines for scouring and milling, and new machines for related processes were installed in the adjoining buildings. The old fulling stocks that were still in use in the early 1880s were probably finally removed with the construction of the shed. An unnamed Fox wrote in 1893-94: 'Have begun the new Mill House – will be a splendid place when finished but will take some time'; and was extremely pleased with the way the work was going the following year: 'The portion of the shed that is completed is a grand place. The machinery is better organised & with a vastly superior light we hope to get our goods better finished'.[37] He was delighted with the finished building in 1895-96: 'At last the new shed has been practically finished & is a vast improvement...A system of packing has been organised to a certain extent & the work generally has been better done the result of better accomodation [*sic*], machinery light &c.'.[38]

20th-century development

Few alterations were made to the Dye Works and Finishing Works after c1900. Scouring and milling machines were added to the Finishing Works for several years after its construction, and some improved types of dye vats were introduced, but in general both areas retained their late 19th-century

power systems and machinery layouts. The most significant new buildings at the site concerned the production of white cloths and the introduction of a new electric power system (Figure 11).

Alterations to machinery

The company archives indicate that many of the scouring and finishing machines were replaced in the mid-20th century. Both types of machine involve heavy wooden rollers working under compression which require regular maintenance, as do the liquor tanks of the scouring machines.

An interior photograph of the Finishing Works, published in 1912, shows the original machinery, with scouring or combined machines in the south row and milling machines in the north row, suggesting that the extant machines are in the original layout (Figure 12). Differences in the framing of the machines, however, indicates that the actual machines in the photograph have been replaced. The *in situ* combined scouring and milling machines in the south row probably date from the early 1930s.[39] The line shafting in the photograph is very similar to the extant shafting, although the section shown extending north from the wheel chamber was later removed (see Description and Analysis of Buildings). The line-shaft pulleys have been moved or replaced during maintenance.

The line-shafting system of the Finishing Works was designed to be powered by steam or water, or a combination of both. The existing water wheel and parts of the wheel chamber were retained and modified to drive an overhead line shaft that was connected to the steam-powered shafting (see Description and Analysis of Buildings). The water-powered shaft could be disconnected by means of a friction clutch, most of which remains *in situ* above the wheel chamber. The clutch itself is of interest, being a type patented in 1887 which was designed for 'transmitting power from a shaft or prime mover, to a wheel or pulley, by which means machines... may be... driven' (Figure 13).[40] The description in the patent specification indicates that the clutch at Tone Works was intended to be driven from the water wheel; the use of a friction clutch in this position suggests that the water-powered shaft could be connected while the steam-powered shaft was still in motion (see Description and Analysis of Buildings).[41]

Other notable new machinery included the water-softening plant, a new tentering machine and new milling machines. Two concrete lime soda water-softening towers were built on a platform above the north-east corner of the ponds in 1913-14, and in 1927-28 a Permutit water-softening plant was installed in a room adjoining the west side of the boiler house[42]; the two systems were used to provide treated water at slightly different pH levels for use in the boilers and the scouring machines. A large Kranz tentering machine was installed in the North Dry House in 1928-29 and is still *in situ*.[43] The first floor was removed to accommodate this machine, which enabled the efficient drying of large quantities of cloth while controlling the amount of shrinking. New milling machines were installed in the early 1930s in the eastern half of the north row, and remain *in situ*.[44] These are generally similar to the earlier machines but more heavily built, with solid cast-iron sides; a partially-dismantled machine of the earlier type, with a cast-iron frame and timber panelling, has been abandoned in the yard.

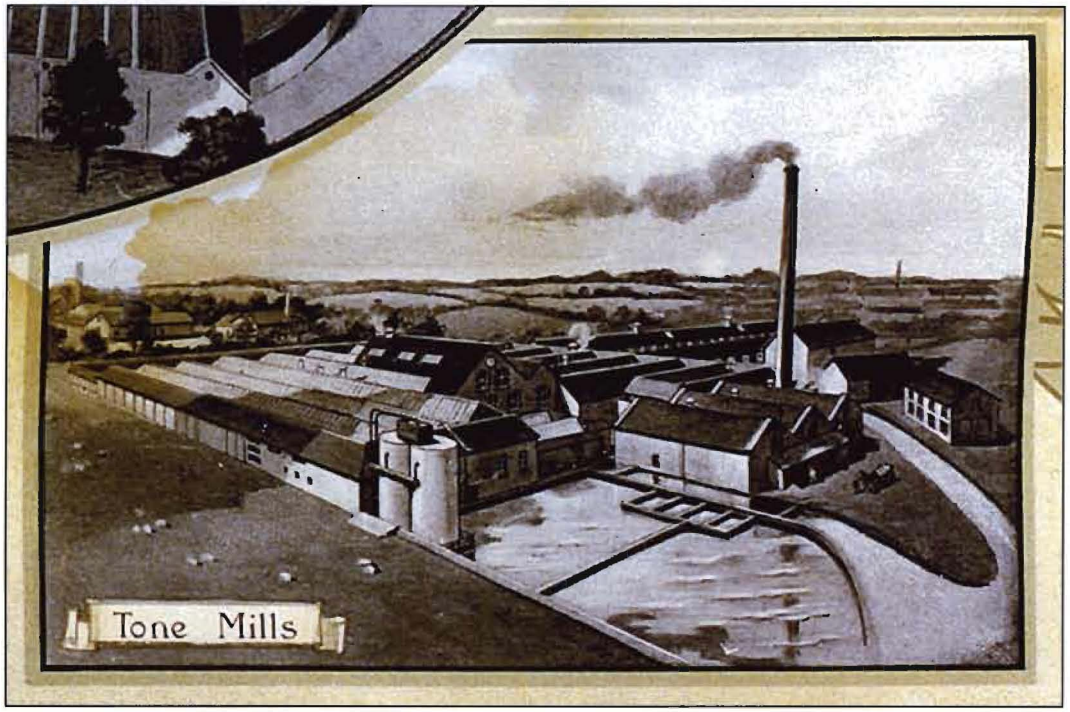


Figure 11.
A depiction of Tone Works from the north-west c1920. Courtesy Fox Brothers & Co archive. [AA95106574]

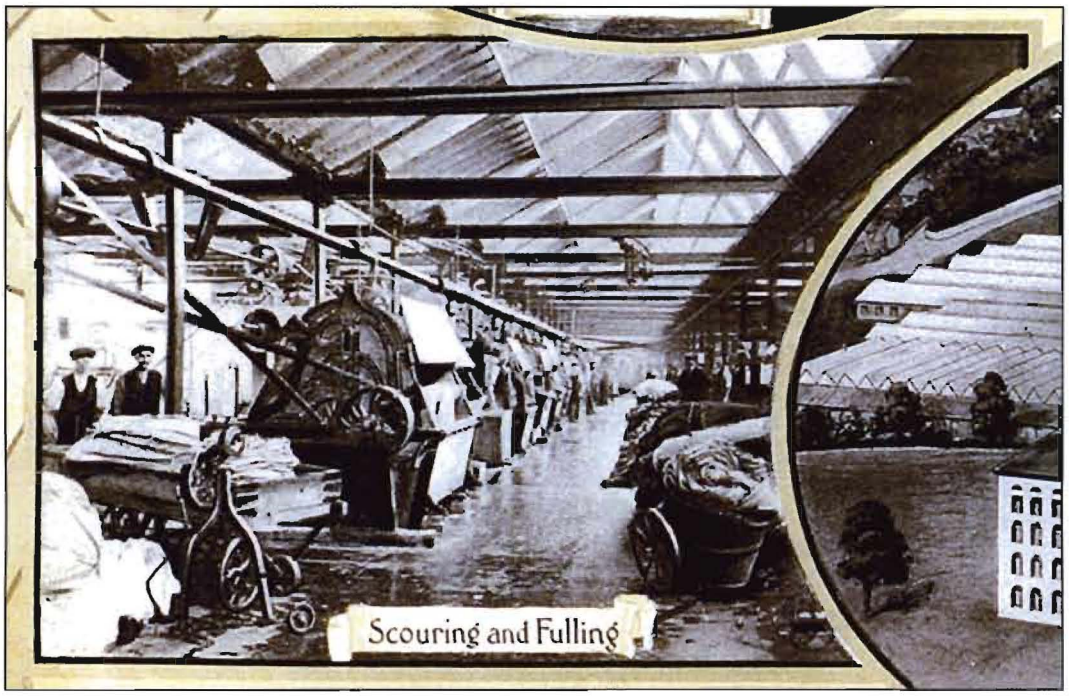


Figure 12.
Interior of the Finishing Shed in 1912, taken from the east end, facing west. Courtesy Fox Brothers & Co archive. [AA95106574; also published in The Gentleman's' Journal, 1912]

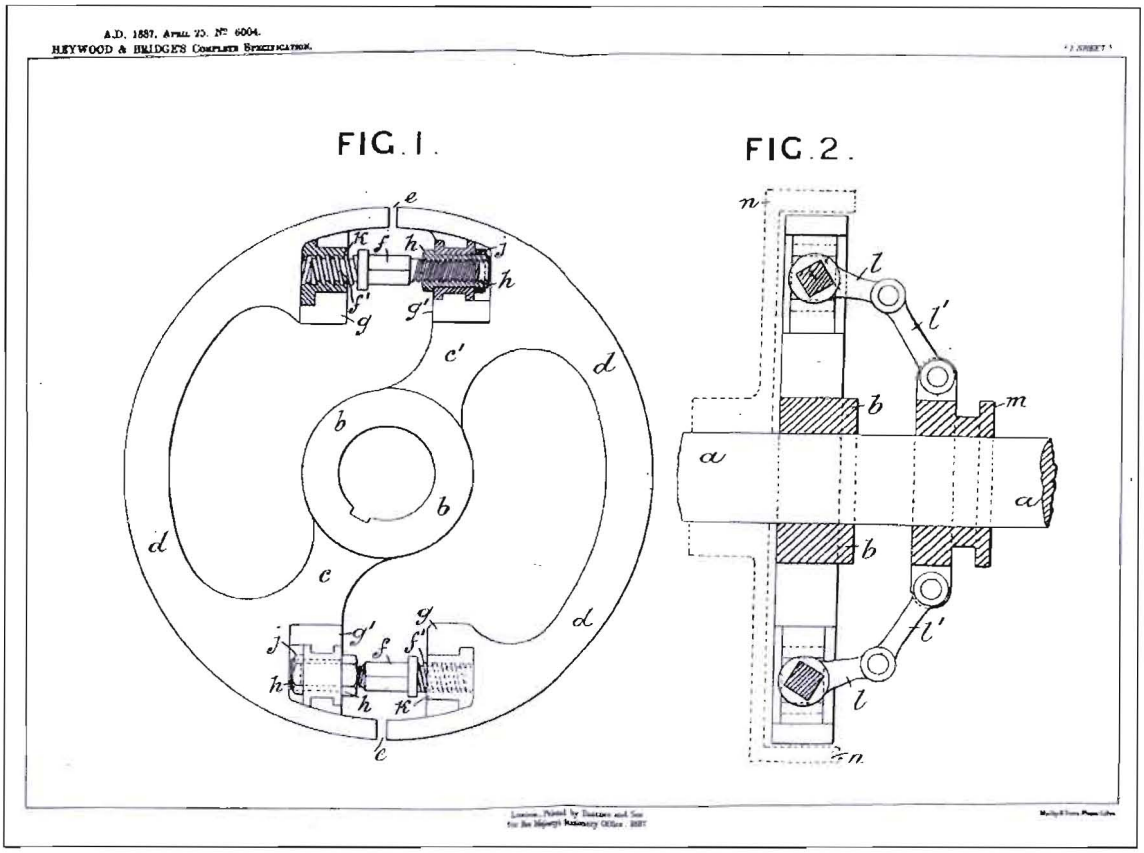


Figure 13.
Patent drawing of the Heywood Friction Clutch, 1887 [Patent 6004, 25th April 1887, British Library].

Fewer references have been found to new machinery in the Dye Works, possibly indicating that the dye vats, and the winches used to feed the cloth through the liquor, did not require as much maintenance as the scouring and milling machines. In 1923-24 F.H. Fox recorded 'Great alterations in the Dye House. A number of small square indigo vats were removed and replaced by boiling vats and cooling vats.'[45] The Dye Works declined in use in the mid-20th century and was closed by c1950.[46]

Buildings for white and grey cloths

From the late 19th century white and grey cloths were in high demand and were produced in separate areas to avoid contamination of the colour from darker cloths. A 'White Room' was added to Tone in 1888-9; this was probably building 4 on the block plan (see Figure 10 above), which is shown in its original single-storeyed form on the c1886 letter head and was extended and raised to two storeys by 1904 (Figure 14; see Description and Analysis of Buildings).[47] In 1913-14 another building known as the 'Crystal Palace' was added for special heavy-milling of khaki and grey cloths[48], possibly building 29 on the block plan. In 1930-31 this was re-equipped for finishing pure white cloths.[49]

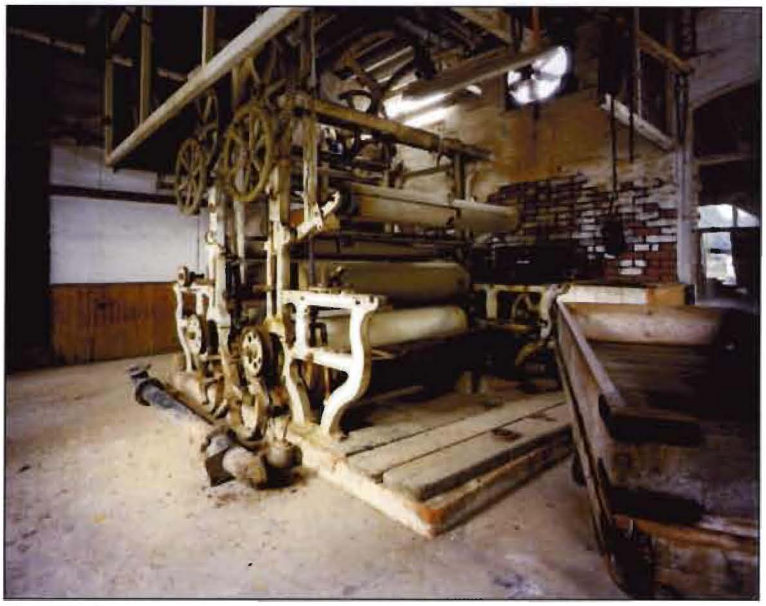


Figure 14.
Machinery in Building 4 in 1995, later removed. [BB96/01711].

The electric power system

Electric lighting was first installed at Tone Works in 1893-94 and at Tonedale a year later[50]; DC electric lighting was fairly commonplace in larger textile mills by the mid-1890s, usually with DC generators driven from the steam engine. The first reference to electric motive power at Tone Works mentions a motor and related fittings in 1915, although its location is not known.[51] It is possible that the motor room adjoining the Finishing Works engine house was originally intended as a location for generators driven from the steam engine (see Description).

A major overhaul of the Tone Works power system took place in 1921-22 with the construction of a self-contained Power House on the south side of the river. This provided power for the DC motors and lighting and steam for heating and processes for the whole site. The new building comprised a boiler house, economiser house and chimney with an adjoining generator room.[52] Part of an earlier small building on the site, marked 'Carpenter's Workshop' on the 1921 Building Control Plan, was incorporated into the new structure and a new access road and bridge gave direct access to the Power House from the site entrance (Figure 15).[53] In the mid-1990s the Power House was remarkably well-preserved with most of the original steam plant, generator sets and fittings, but at the time of survey it was not accessible due to asbestos contamination.

The new power system required expenditure of around £30,000 on buildings, plant and machinery between 1921 and 1924. This included three Lancashire boilers and a Greens Economiser, high-speed steam-engines, generators and a switchboard for the generator room, and motors, starters and control panels for use throughout the site.[54] The archive includes reference to the 62 hp and 120 hp DC motors that remain *in situ* in the Motor Room, both purchased from Mather and Platt in 1921-22.[55] In 1949 another DC generator set was purchased for the Power House, with a

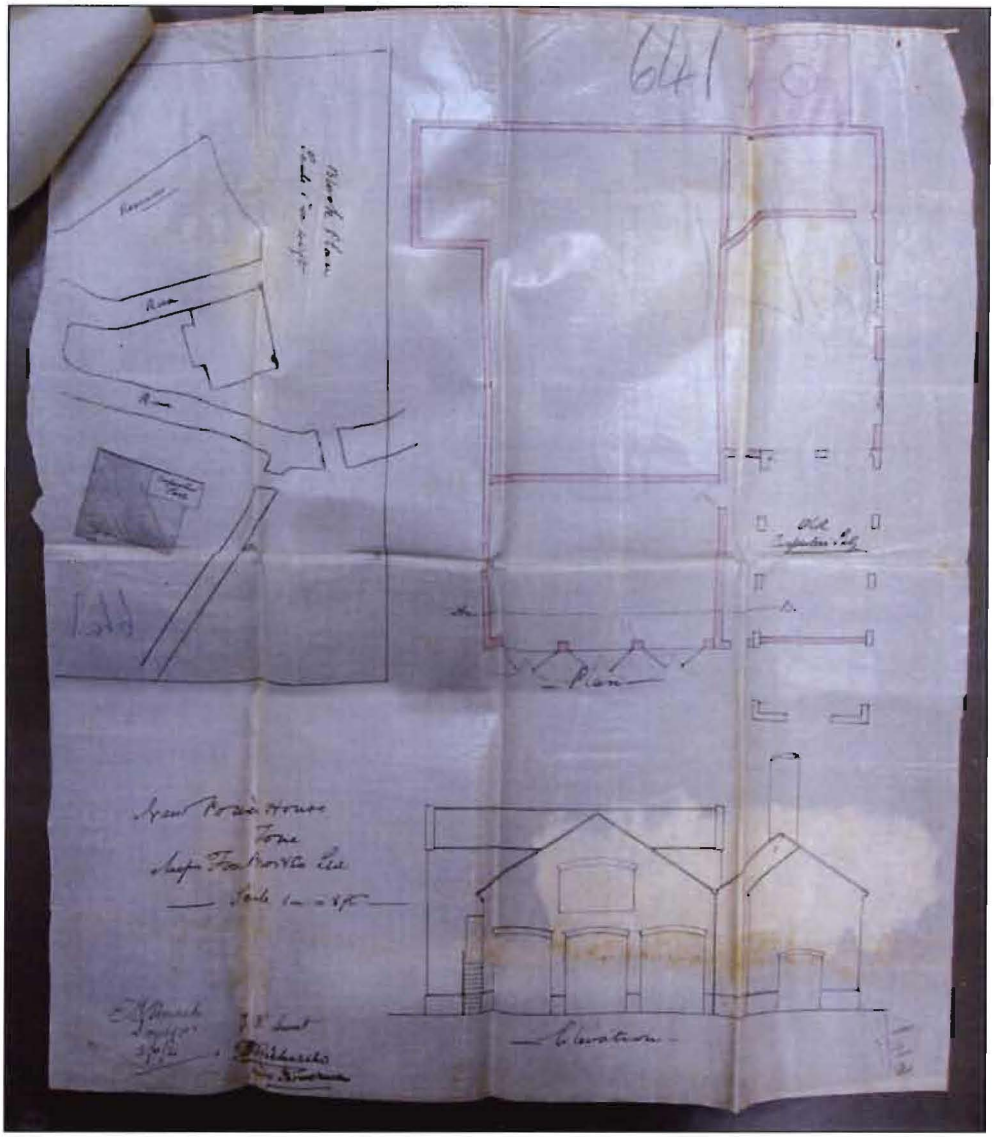


Figure 15.
1921 Building Control Plan showing the proposed layout of the new Power House.
[SARS D\U\wel/24/1/3/641; original held at the Somerset Record Office. Used with permission].

Bellis and Morcom engine.[56] AC motors were later installed in many locations around the works, including two large motors to drive the line shafting in the Finishing Works. The original 1895 steam engine for the Finishing Works was scrapped in 1943, and the water wheel had stopped being used by 1947.[57] In the late 20th century the old DC motors were kept in working condition so that the Finishing Works could be driven by either DC or AC power; the existing clutch in the Motor Room was used to switch between the AC and DC motors.[58]

A SUMMARY OF PROCESSES AT TONE WORKS

Tone Works developed from the early 19th to the early 20th century to dye and finish the wide range of woollen and worsted cloths that were manufactured by Fox Brothers. When the works reached its maximum extent in the early 20th century it was subdivided into a Dye Works and a Finishing Works, each comprising a range of processes located in buildings with distinctive functional features. The Dye Works was centred on the early part of the site, most of which had been rebuilt and extended in several phases. The Finishing Works was located in a north-light shed that was added with a new engine house and other buildings in 1893-5. Before the construction of the new shed both sets of processes must have been located in the earlier parts of the site; this account concentrates on the final arrangement of processes, as indicated by the surviving machinery. The Dye Works closed around the middle of the 20th century, but the Finishing Works remained operational until c2000. In general, woollen cloths were dyed 'in the cloth' and worsteds were dyed as yarns or as raw wool, but the exact sequence of processes varied greatly. In the 1990s the Finishing Works was processing cloths which had already been dyed elsewhere, and this may have been the normal procedure following the closure of the Dye Works. A description of the site in the early 20th century, however, states that cloth was finished *before* it was sent to the Dye Works.[59]

The Dye Works

By the end of the 19th century Fox Brothers were noted large-scale dyers, particularly of indigo and khaki cloths, and Tone Works was claimed to be one of the most technically-advanced dyeworks of its type in the country (it is currently the largest identified historic dyeworks in the South West).[60] The external features of the Dye Works buildings reflect their internal functions, and the complexity of this part of the site is an indication of the variety of dyeing processes and their development between the early 19th and the mid-20th centuries.

The dyeworks area has not been accessible during the current survey. Documentary sources, photographs taken in the 1990s and information kindly provided by Michael Fox and Jack Hudson has enabled a general assessment of the type and significance of the surviving machinery (Figure 16). Dyeing had ceased by the middle of the 20th century, and there has been little maintenance of the buildings in recent years, but machinery, line shafting and fittings which are of historic interest have all remained in place.[61]

In 1912 the Dyeworks was described as 'perhaps the largest Indigo Dye House in England' and was said to contain around 30 vats.[62] When it ceased operation it still contained around four indigo vats, along with vats used for other dyestuffs, an under-floor dye storage tank and a large cast-iron tank for softened water. The dye vats and related machinery are located in buildings 8 and 10 on the block plan (see Figure 10 above). It was a 'piece dyehouse' which was claimed to have the only continuous indigo dye vats in the country.[63] Cloth pieces were stitched end-to-end into a continuous loop which passed through a system of rollers, known as dye winches, located above the rectangular vats. The rollers were arranged so that the cloth was repeatedly dipped into the boiling liquor as it passed through the machine, thus speeding up the dyeing process. The dye winches appeared to have been belt-driven from line shafting when inspected briefly in the 1990s.

Figure 16.
Interior view of the Dye Works in 1995, showing in situ dye vats, winches and intact line shafting. [BB96/01695]

The parts of the Dye Works that were built to contain dye vats were equipped with large roof ventilators. Buildings 8 and 10 on the block plan (see Figure 10 above), dating from the 1880s and 1890s, had prominent metal cylindrical ventilators mounted on the apex of the north-light roof. Adjoining to the east, building 12 appears to pre-date the shed (see below) and is roofed separately. Its heavily-built timber gabled roof has prominent full-length ventilation louvres, suggesting that this area also formerly contained dye vats. Building 21, built across the head race to the north-west, was known as the Streaming Shop and was functionally related to the dye works. Dyed cloth was rinsed in the flowing water of the head race to remove surplus dyes; this was especially important in the 19th century when colours could not be adequately 'fixed' by chemical dyes, and because Fox Brothers produced large quantities of dark-coloured cloths.

Finishing Works processes

Finishing the dyed woollen and worsted cloths involved scouring, milling, tentering, raising and cutting. This sequence of processes was repeated for the better-quality woollen cloths, and variations were made to each stage to control the quality of the final product. An important part of the success of Fox Brothers was their successful development of cloth finishing techniques, and of scouring and milling in particular. The scouring and milling stages were equivalent to the slower fulling process that was widespread in the woollen industry up to the early 19th century. Thomas Fox is said to have developed the technique of dividing fulling into 'wet' scouring followed by 'dry' milling, and of repeating the whole sequence of finishing processes to produce high-quality fine woollen flannels.[64] The firm also finished a range of other cloths at Tone Works. Worsteds were scoured but not milled, and lower grades of woollen cloths were finished more quickly in combined scouring and milling machines. These combined machines were the type that was most widely used by other firms (Figure 17).

Figure 17.
General view from the east end of the Finishing Shed; compare with Figure 12.
[DP043932]

Figure 18.
Three cloth pieces being scoured at Tone Works in 1995. [AA96100664]

Scouring was a heavy washing process in which oils, fluff and surplus dyes were removed from the cloth.[65] After dyeing, the cloth was taken to the scouring machines in which it was passed through a liquor of hot water mixed with a soda solution (soap), which was then squeezed through the cloth between heavy wooden rollers (Figure 18). The ends of each piece were stitched together as it was fed into the machine to form a continuous loop, in a technique known as 'rope scouring'. The cloth was then repeatedly passed through the scouring machine for several hours; up to four pieces could be scoured side-by-side in each machine. The stitching was done with small portable sewing machines, many of which still remain on site. Depending on the type of cloth being produced, the edges of the piece might also be stitched together on a different type of sewing machine to form a continuous tube, which in Tone Works was known as 'bagging'. This increased the efficiency of scouring, as the liquor inside the tube was squeezed out evenly across the full width of the piece (Figure 19).

In milling machines high-pressure rollers caused the cloth to shrink and to attain a matted surface in which the warp and weft threads were no longer visible. Milling was a 'semi-dry' process which did not involve further soaking of the cloth in hot liquor, although when the cloth was in the machines it was deliberately kept damp and a small amount of soap added. The milling machines are narrower, since

Figure 19.
'Bagging' a cloth piece at Tone Works in 1995. [AA96100644]

cloth was milled one piece at a time, and more heavily constructed than the scouring machines. They are grouped beneath the primary line shaft in the eastern half of the shed, and are not positioned above an open drainage channel (Figure 20).

Figure 20.
Milling machines grouped along the north side of the Finishing Shed; compare with Figure 12.
[DP043933]

After milling the cloth was tentered, or dried with a controlled amount of shrinking, which was carried out in the North Dry House adjoining the shed. Structural features in the dry house suggest that in the 19th century cloth was dried using a combination of heated air and natural ventilation through the louvered side panels (see Description and Analysis of Buildings). The pieces would have been stretched along the building using tenter hooks attached to racks and ceiling beams, some of which remain in place on the late 19th-century tie-beams in the attic. In the late 1920s the lower two floors of the dry house were modified with the installation of a large tentering machine which enabled the cloth to be dried much more quickly. This remained in use until the late 1990s.

The final stages in finishing involved raising the knap of the cloth and precisely cutting its face using rotary shearing machines to achieve the desired texture and appearance. Two types of raising machines are located in the south-east corner of the finishing works, and another in the adjacent dyeworks. They used a system of rollers to brush the surface of the cloth in order to extend the matted fibres formed in milling. One of the accessible machines, which appears to be of mid-20th-century date, uses traditional teazles mounted on wooden blocks (machine 46, Appendix 3); teazles continued to be the preferred method of raising the knap of the highest-quality fine woollen cloths. The other machine used wire brushes to produce a different kind of finish for some specialised types of cloth, such as that used for covering snooker tables. Shearing off the raised knap was a dry

process which was kept separate from the damp environment in the scouring and milling areas. The two *in situ* shearing machines are of late 20th-century date. In the 1990s they were positioned in a new room built inside the Finishing Shed which was equipped with extractors to remove the loose woollen fibres (Figure 21).

Figure 21.
Detail of a modern rotary shearing machine. [DP043912]

A SUMMARY OF THE POWER SYSTEMS AT TONE WORKS

One of the most significant aspects of Tone Works is the exceptionally well-preserved evidence of its water, steam and electric power systems. The survival of all three power systems is highly unusual; no other mill site is known to retain the same combination of large-scale power features spanning the full date range of the traditional textile factory.[66] An important factor in the preservation of the power systems was the uninterrupted management of the site by Fox Brothers, whose efforts to retain traditional methods of cloth finishing in the 20th century precluded the extensive modernisation of machinery and buildings.

The complexity of the power systems is in part a consequence of the gradual expansion of the site in the 19th century, which was typified by frequent rebuilding and many small-scale additions built to contain particular processes. Line shafting had to be extended into new buildings or modified to drive new processes in existing buildings, and in those parts of the site where an adequate power source was available it was retained alongside the new installations (Figure 22). The piecemeal development of relatively small buildings at Tone Works (and other textile finishing works) created a site which contrasts markedly with the rectangular layouts of spinning and weaving mills; the latter often required a simpler arrangement of line shafting.

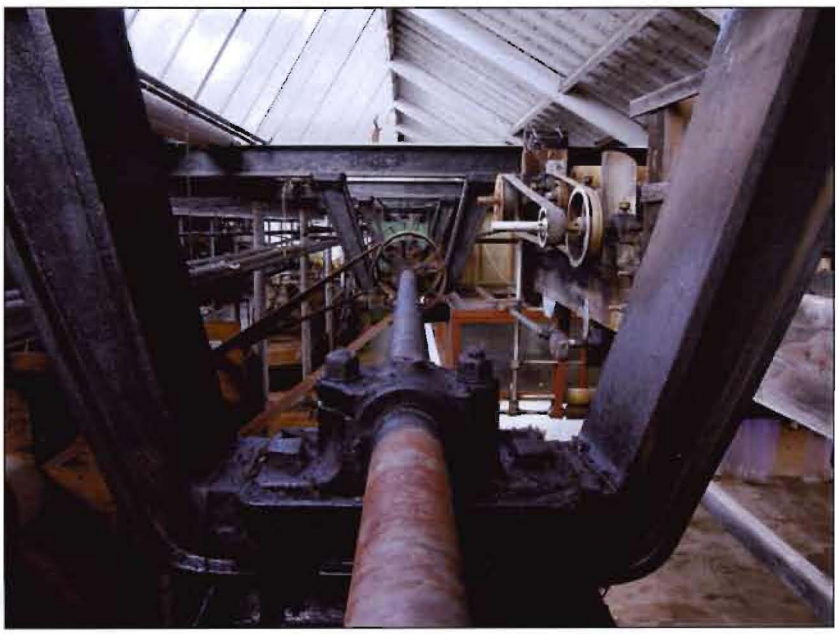


Figure 22.
The South Line Shaft in the Finishing Works. [DP046033]

Evidence of the power systems comprises buildings, landscape features and the intact components of the late 19th-century power-transmission system. The original water power system determined the layout of the site and continued to influence its development after new sources of power were added. The most significant water-power feature is the early 19th-century Wheel Chamber, which

survives beneath the roof of the 1895 Finishing Works. It retains substantial parts of a breast-shot suspension wheel, the intact penstock and the later belt-drive system. It originally powered a group of early 19th-century buildings on the site of the present Dyeworks, but was later adapted to drive both the rebuilt Dyeworks and the Finishing Works in combination with the steam power system. The two power sources were combined using a friction clutch mounted on the shafting above the wheel chamber. Also associated with the wheel chamber are the culverted head race and tail race, with additional sluices, bypass channels, ponds and other landscape features extending well beyond the buildings of the site.

There is good evidence of several phases of steam power, which was used in combination with water power. Mid- and late 19th-century steam engines and boilers are likely to have been located in the Dyeworks, but their sites are not currently accessible. When the Dyeworks was rebuilt in c1880, the detached late 19th-century Boiler House was added in the yard on land reclaimed after the straightening of the River Tone. This larger boiler house formed a centralised steam plant for the whole site, with a system of piping providing steam for engines and hot water for processes. Fox Brothers built another centralised power plant at this time at Tonedale Mills.

The construction of the new Finishing Works in 1894-5 included a new attached Engine House, which used steam from the existing boiler house (Figure 23). The 1894-5 power transmission system appears to be completely intact, and may be the oldest intact example in the country.[67] It comprises a system of belt- and gear-driven line shafting occupying the full length of the Finishing Works and

Figure 23.
The 1893-5 Finishing Works Engine House, on the right, with the adjoining Motor Room, overlooking the soft-water reservoir. The two concrete towers are the lime soda water-softening plant installed in 1913-14. [AA96/00690]

extending into the adjoining Dye Works. Heavy-duty clutches enabled the line shafting to be driven by a combination of different power sources. The earlier water wheel chamber was extensively modified at this time so that the line shafting could be both water and steam powered. The rebuilt water-powered transmission system, comprising spur gears and a belt drive installed alongside the wheel chamber, also survives intact.

The intention to add an electric power system was apparent in the layout of the 1893-5 buildings, although the extant motors were added later. Attached to the north end of the new engine house was another new building, which is referred to as the Motor Room in this report. Internally this was open to the roof and contained the end of the primary line shaft. It housed the drive belt from the engine to a large pulley which remains attached to the end of the primary line shaft, although its dimensions suggest that it originally also contained some other function; it is much larger than the typical belt or rope races found at other textile mills. The empty space may have been originally used for electric generators or DC motors (see Description and Analysis of Buildings, below).

In 1922, when the new detached Power House was built on the south bank of the river, the two *in situ* DC electric motors were installed in the Motor Room and used to drive the existing line shafting and machinery, neither of which appear to have been altered with the addition of electric power. This is now a rare intact example of a 'group-drive' system, an early stage in the introduction of electric power in which large motors were used to drive groups of machines via shafting that was originally driven by a steam engine. By the mid-20th century most of these installations had been replaced by smaller AC motors attached to each machine, when the line shafting was dismantled. At Tone, more efficient AC motors were installed in the Engine House and Motor Room in the mid- and late-20th century, but continued to drive the 19th-century line shafting in a group-drive system. The older DC motors and belt drives were retained and used alongside the AC motors. It is not clear when the site became entirely electrically-powered, but the steam engine and water wheel were both disused by the late 1940s.

DESCRIPTION AND ANALYSIS OF BUILDINGS

Tone Works is located on the west side of Milverton Road, to the north and south of the River Tone. The principal buildings and features are marked on the Site Plan (Figure 24). The original site entrance was to the north of the river, and this is where the largest buildings used for dyeing and finishing are situated, together with the ponds and the head race. To the south of the river are the present main entrance, one of the two early dry houses and most of the 20th century additions, including the 1922 Power House. The following building descriptions are arranged in chronological order.

The South Dry House

The South Dry House is the earliest intact building at Tone Works. It comprises an original central section, which is marked on the 1839 Wellington Tithe Map, with later extensions to both ends and along the west side. It has decayed in recent years, but is of interest as one of the best-preserved early dry houses in the South West, retaining most of its historic structural features. Specialist cloth dry houses, long narrow structures which usually combined heated and open-air drying, were a feature of the larger integrated mills in the 19th century, but fell out of use with the introduction of machine tentering and were often demolished (Figure 25).

The original section is of two storeys and thirteen bays with rubble walls, small rectangular windows and a pantile gabled roof. Its Milverton Road elevation is more reminiscent of local vernacular buildings than of the 19th-century factory architecture found in the later parts of the site. The walls have an internal brick lining, and the windows have red-brick sloping sills, heads and straight jambs. A distinctive feature is the blocking of windows in alternate bays; the blockings alternate between the east and west sides in successive bays, possibly to prevent strong air flows across the building. The blockings are of different dates, but many are of similar red brick to the window jambs, suggesting that they are an early modification. The glazing bars have been replaced and the site of the original entrance is not known. Parts of the ground floor retain original 12 inch square clay tiles (many of which have been removed recently). The first floor is of heavy joisted construction supported by timber beams and occasional inserted timber props. The beams have shallow full-width mortices in the soffits, possibly for racking to support the cloth. A straight staircase is located against the east side, close to the joint with the north extension, together with parts of a tongue-and-groove box partition. The staircase appears to date from the late 19th century, but may be on the site of the original stair.

The upper floor is open to the gabled roof, which has an original plaster-on-lath ceiling attached to the rafters, presumably for insulation. The roof trusses comprise half-lapped principals with tie-beams at eaves height, a high collar supporting a short post, angled queen struts and a single rank of square butt purlins. The apex supports a diamond-set ridge piece and the purlins are morticed and pegged, all typical features of semi-vernacular industrial roofs of the very early 19th century. Some of the tie-beams retain rows of tenter hooks, and the soffits have similar shallow mortices to the ground-floor beams (Figure 26).

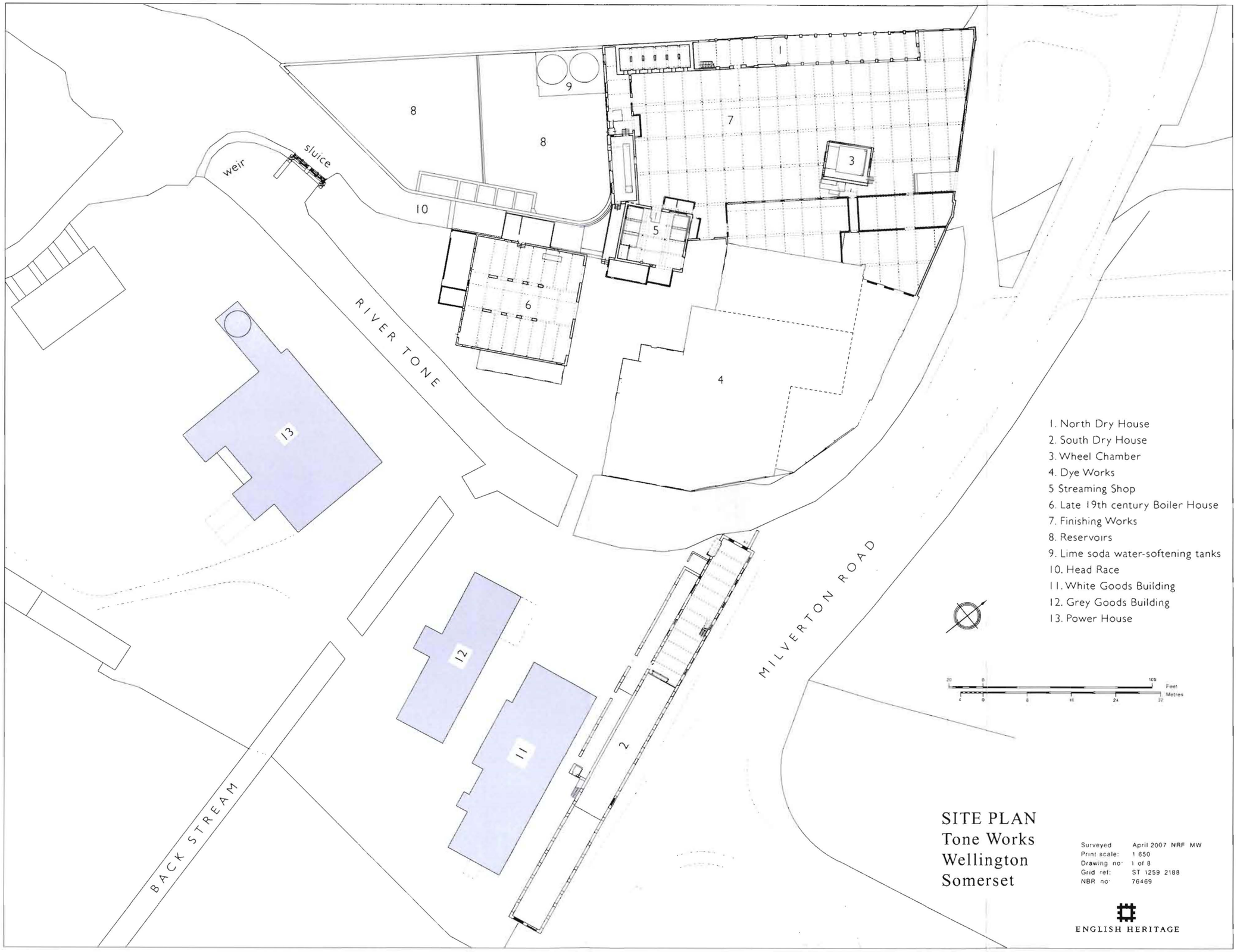


Figure 24. *Tone Works site plan, surveyed April 2007*

Figure 25.
The South Dry House. [BB96/01703]

Figure 26.
Attic of the South Dry House. [AA96/00720]

The original north end wall has been removed and the building is open into the extension on both floors; the position of the extension is marked by a slightly wider bay. The walls and windows of the extension are of generally similar construction, although differences in the roof structure suggest it was added in the mid-19th century. The trusses do not have collars or posts but support a square-set ridge piece, and narrower purlins are supported by iron straps. There are no mortices in the tie-beam soffits of the extension.

The south end extension, which is shown on the 1889 O.S. plan, is of distinctive pier-and-panel construction (Figure 27). The piers are of similar proportions to those in the North Dry House, but built in a light grey brick. The building has not been accessible. Most of the original opening louvres in the panels have been replaced, but their former positions are indicated by paint stains on the sides of the piers. Some opening panels survive intact in the upper storey. The roof trusses are of sawn timber and have wide collars at the level of the purlins, but no tie-beams; there is no plaster ceiling. The south end of the original building has been removed, and stone walls of the earlier phase extend into the first bay of the extension; this suggests that the earlier building had a single-storeyed projection at the south end, a possible site for an external stove for warm-air drying.

A long single-storeyed lean-to extension is attached to the west side of the first two phases, and was probably added shortly before the south end was extended. It is of similar conglomerate stone rubble to some other mid- and late 19th-century buildings at Tone Works and Tonedale, but has window and door jambs of red brick which suggests a late 19th-century date. The building has partially collapsed and was thus not accessible.

Figure 27.

The pier-and-panel extension of the South Dry House (right), and the White Goods building (left). [BB96/01710]

The North Dry House

The North Dry House is also marked on the 1839 Wellington Tithe Map, when it was roughly the same length and width as the extant building, but has more alterations than the South Dry House. Structural evidence indicates at least four phases of partial demolition and rebuilding, but also suggests that a substantial part of the pre-1839 structure may survive. It was longer than the South Dry House with three drying floors, including the attic, and its position close to the other early buildings suggests that it may have been the original dry house at the site. It comprises a pier-and-panel section at the east end attached to a short stone-built central section, with two phases of late 19th-century rebuilding attached to the west (Figure 28).

Figure 28.
The North Dry House, with in situ ventilation louvers to the left of the rubble wall. [DP046034]

The earliest phase is probably the single bay of stone rubble construction, located eleven bays from the east end. This is of similar stone to the early parts of the South Dry House and probably dates from roughly the same period. The top of the south elevation, which now overlooks the Finishing Shed roof, incorporates three dove holes built in similar hand-made red brick to that used in the jambs of the South Dry House. The Tithe Maps shows a yard or roadway adjoining the building at this point, suggesting that an original entrance may have been located beneath the dove holes. The O.S. plan surveyed in 1886-7 shows a cross-wall in this position, although no internal evidence of a cross-wall survives. The rubble walls may be the last surviving part of a longer original structure, perhaps of similar appearance to the South Dry House. Alternatively, stone may have been used in this area for functional reasons, such as accommodating a hot-air stove (Figure 29).

The adjoining pier-and-panel building to the west is of ten bays and of similar construction to the extension of the South Dry House, but with piers of earlier red brick. The panels on the south side were blocked when the Finishing Shed was built, but most of those on the north side retain their opening wooden louvres. Internally, the first floor was removed in 1928-29 when the *in situ* tentering machine was installed; the blocked sockets of the former floor beams can be seen in the piers. The attic floor survives intact, however, with roughly-chamfered heavy beams and square-section joists, suggesting an early to mid-19th-century date. Other examples of pier-and-panel industrial buildings are known to date from the 1830s, so it is possible that the brick piers and the attic floor survive from the building shown on the Tithe Map.

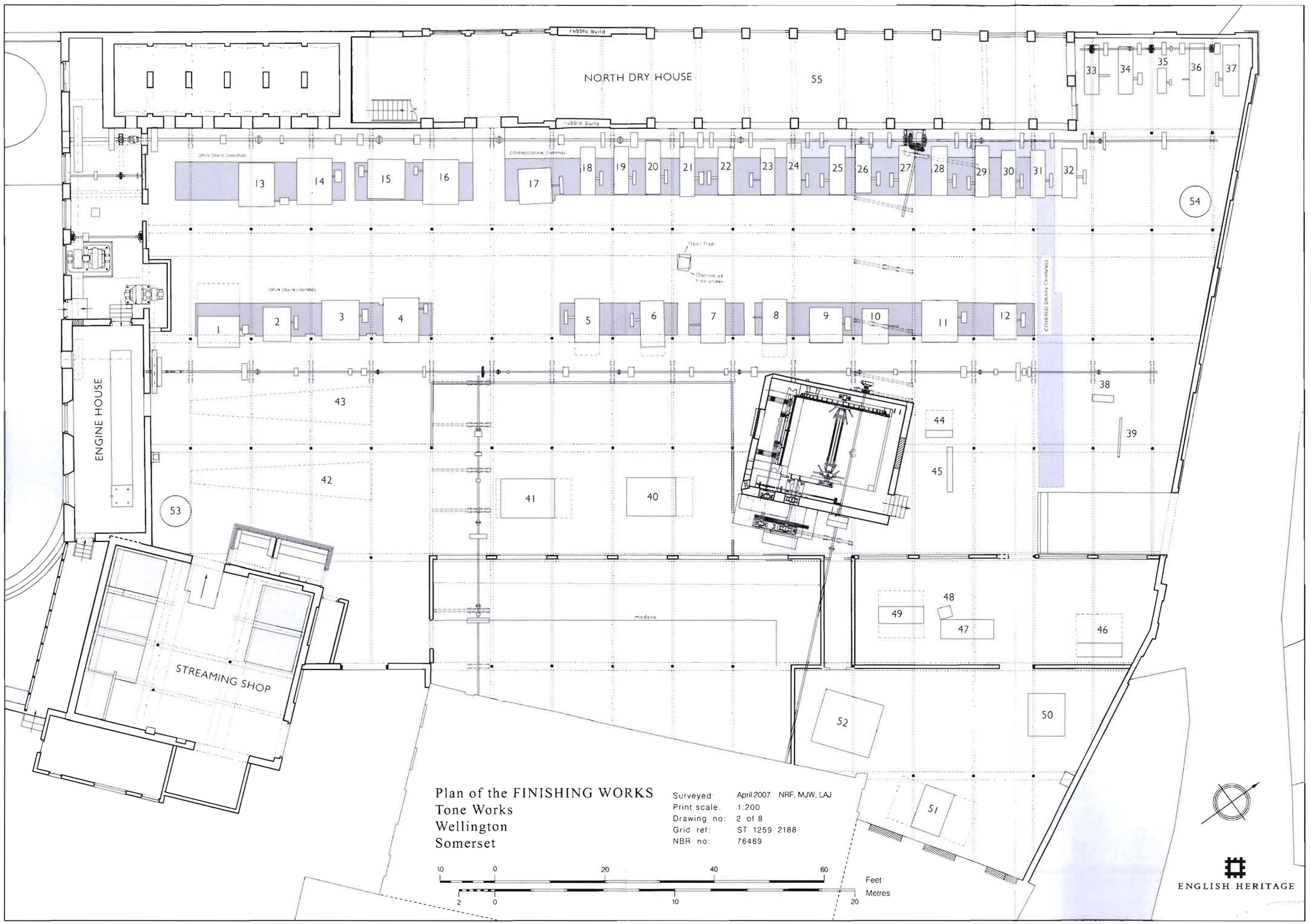


Figure 29. *Plan of the Finishing Works, surveyed April 2007*

The surviving panels in the north side are probably later replacements. The opening louvres are now mostly fixed in place, but their wooden mechanisms survive, comprising tapered hinges pivoting on wooden pegs which could be opened from below using a cord attached to a lever. They may not be original, however, since similar wooden louvres survive in the late 19th-century extension of the South Dry House. In the ground floor, the north side is lit by windows which were probably inserted in the late 19th or early 20th century, although the walls beneath the window sills appear to be original to the piers.

Late 19th-century extensions in red factory-made brick are attached to the west of the section of rubble wall, occupying the same footprint as the building on the Wellington Tithe Map. The three bays adjoining the rubble are separated from the remaining seven bays by a straight joint, although there is no evidence of a cross-wall associated with the joint. The brickwork to the east of the joint is in Flemish bond, while that to the west is in English bond, with alternating courses of headers and stretchers. The section to the east of the joint is contemporary with the c1893-5 reorganisation of the site, and was associated with the water-treatment system of the new Finishing Works. The six end bays contain a single massively-built tank, occupying most of the height of the building beneath the attic floor, which was formerly used to hold softened water for the Finishing Works. It was probably fed from the nearby ponds. The floor of the tank is supported by a series of low walls and brick vaults, accessible from inside the Finishing Shed. The west end of the attic contains the remains of two more iron water tanks of unknown function.

The roof of the whole building was probably replaced in the late 19th century, and may be contemporary with the rebuilt west end. It is of similar construction to the late 19th-century extension of the South Dry House, and to other late 19th-century roofs in the Dye Works area. The roof collars throughout the attic retain rows of tenter hooks, suggesting that the full length of the attic was used for drying (Figure 30).

Figure 30.
The attic of the North Dry House, with tenter hooks on the tie-beams. [DP046035]

The Wheel Chamber and Water-Power System

The wheel chamber comprises a rectangular flat-roofed structure beneath the north-light roof of the Finishing Shed. It is of similar plan and orientation to the external wheel chamber shown on the 1839 Tithe Maps and is probably the modified remains of the early 19th-century water-power system (Figure 31). It contains the well-preserved wheel pit with parts of a suspension wheel, the penstock and good evidence of three phases of power transmission. The chamber is open to the intact head race, which is now culverted beneath the Finishing Shed floor, and the tail race tunnel. The watercourses have not been entered but the positions of both appear to be close to those indicated by the Tithe Maps.

The end walls of the wheel chamber, above the head race and tail race, are probably original, but the north and south side walls are both late 19th-century replacements. The ends are of hand-made red brick bonded with white lime mortar, with central blocked tall arched windows that were originally above ground level. Both ends also have a lower segmental-headed arch spanning the headrace and tailrace. The side walls are of factory-made brick bonded with black mortar, as used throughout the 1893-5 Finishing Works, and were rebuilt during its construction. The flat roof has concrete sections adjacent to the end walls and a lightly-built central joisted section. It is supported by I-section rolled-steel beams, and also dates from c1893-5 (Figure 32).

The wheel pit also probably dates from the early 19th century. It has red brick sides, with projecting piers to support the wheel shaft bearings, and curved ashlar breastwork. A cement section above the ashlar marks the position of the housing for the penstock shutter. The downstream end wall of the pit is entirely of red brick and contains the segmental-headed entrance to the tailrace tunnel. Scrape marks in the north-west corner of the pit suggest that it formerly contained a wheel of a slightly different radius to that of the extant wheel (see below). A partially-flagged walkway around the pit is located 1.37m below the Finishing Shed floor; the walkway may be close to, or just below, the original ground level, which was raised during the construction of the shed. On the south side of the pit, the walkway has a raised step at the west end to give access to the penstock mechanism. Substantial cast-iron mounting plates for pinion shaft bearings are set into the walkways on both the south and north sides of the pit, indicating a complex development of power transmission. The proportions, materials and construction of the wheel chamber are notably similar to the well-preserved external wheel house of Fox's Coldharbour Mill, also of early 19th-century date (Figure 33).

The south side wall of the wheel chamber was entirely rebuilt in c1893-5 to support a belt-drive power transmission for the new Finishing Shed. It is thicker than the end walls, containing the massive cast-iron bearing boxes of the pinion shaft driven by the wheel and the shaft of a large belt pulley used to drive the shed's overhead line shafting. The belt drum and a pair of spur gears remain intact in a separate gear chamber located to the south of the wheel chamber, beneath the Finishing Shed floor. The south wall extends up above the wheel chamber roof to the level of the shed roof, where it supports the massive bearing box of the water-powered line shaft and the upper belt drum. In contrast, the rebuilt north side wall of the wheel chamber is just one brick thick and less well-built, but of similar red brick and black mortar to the south side, suggesting it is of similar date. Its construction blocked another pinion shaft driven from the north side of the waterwheel.

Figure 31.

The Finishing Shed in 1995, showing the wheel chamber on the left. Water- and steam-powered line shafts are suspended beneath the roof. [BB96/01686]

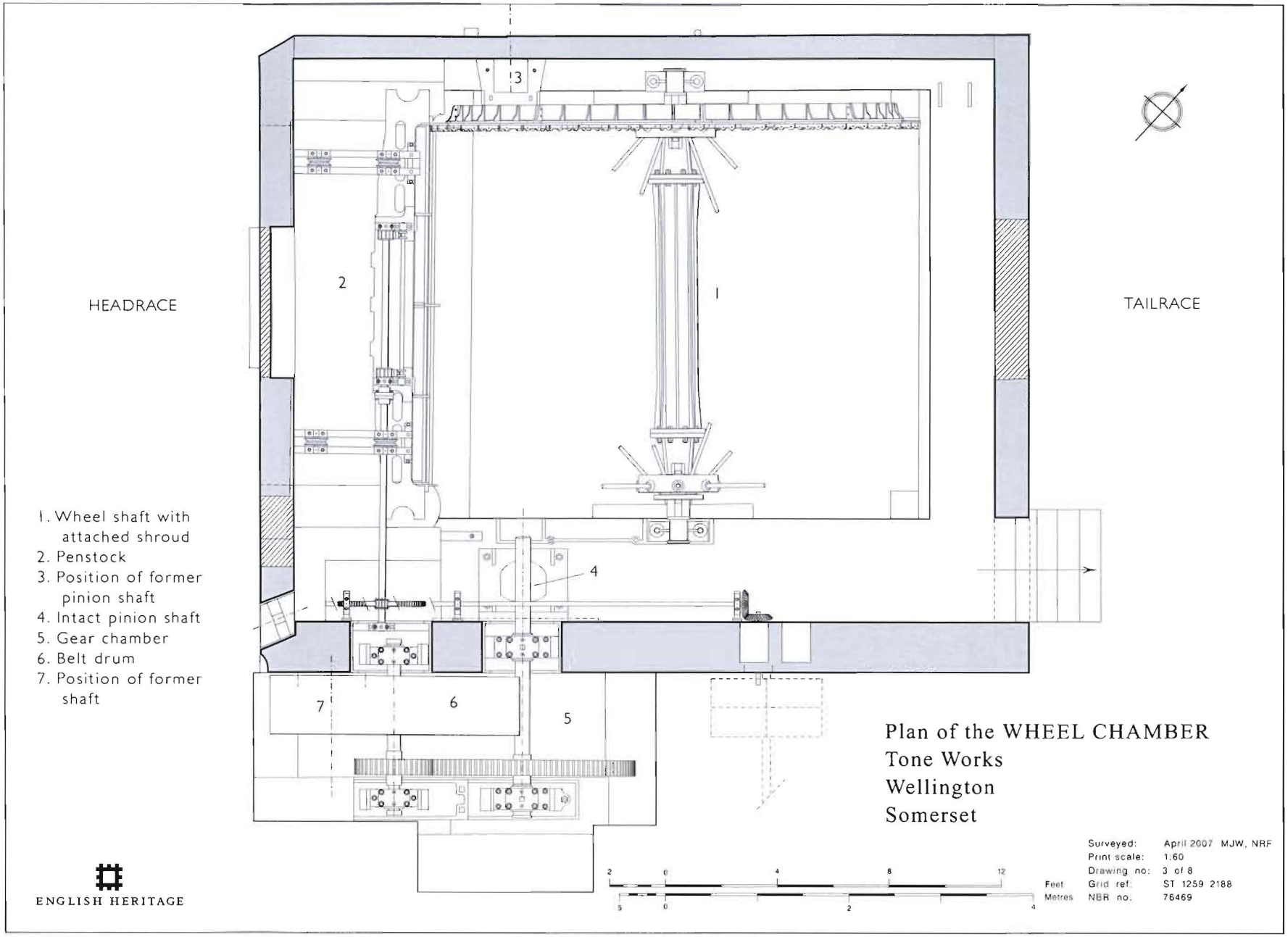


Figure 32. Plan of the Wheel Chamber, surveyed April 2007.

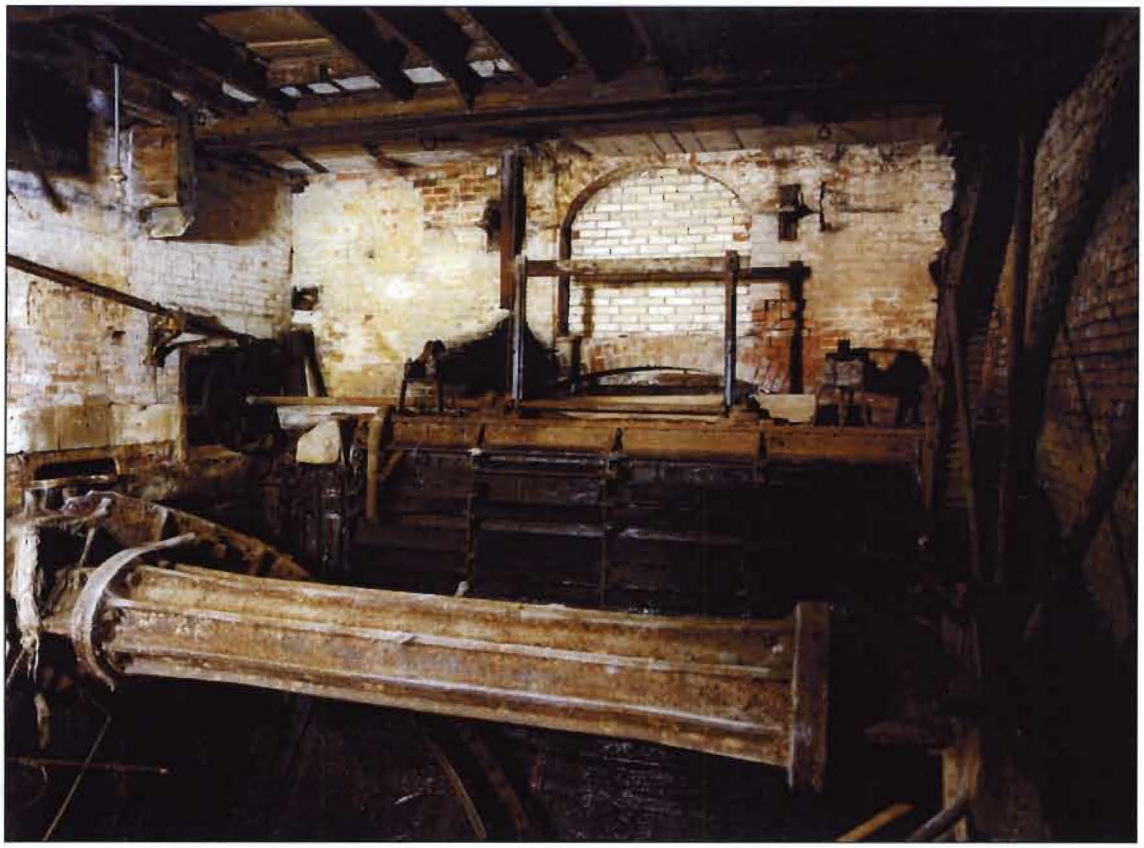


Figure 33.
Interior of the Wheel Chamber, showing the wheel shaft and the penstock in front of the west end wall. [AA96100682]

The water-power system

Water supply

The system for controlling the flow of water to the wheel is intact but post-dates the wheel chamber. The weir and leat were built when the original course of the River Tone was altered in the late 19th century. The 1839 Tithe Map indicates that the wheel was originally supplied from a short leat running from the section of the river that was later removed. The construction of the weir did not significantly raise the head of water, and its main purpose related to improving the site's flood defences. The weir is stone-built to a curved plan composed of four angled straight sections and incorporates a wooden footbridge. The entrance to the leat adjoins its north end. The leat is roughly in the position of the former course of the river, and was straightened into its present form in the 1880s. The entrance does not have a sluice, although the sides have grooved concrete posts for the insertion of stop boards (Figure 24, above).

A large bypass sluice, which appears to be in working condition, is located on the south side of the entrance and is probably contemporary with the weir. It comprises a pair of cast-iron rack-and-pinion shutters to either side of a central brick pier. The shutters were controlled by separate hand-

wheels mounted on pedestals at the ends of the sluice. A later control mechanism employing a small gearbox has been added to the eastern hand-wheel, probably driven by an electric motor in a nearby shed (Figure 34).

Figure 34.
The headrace and bypass sluice in 1995. [AA96 00645]

The open leat follows a direct course to the works where it passes beneath the Streaming Shop, in which dyed cloths were washed in the flowing water (see Dye Works, below). Additional sluices were installed in the Streaming Shop to direct water from the leat through an under-floor effluent tank located beneath the south-east corner of the Finishing Works. The head race is culverted beneath the yard and the concrete floor of the Finishing Shed, and seems to follow a similar indirect course to that indicated on the Tithe Maps; it turns sharp left after the Streaming Shop and then right into a straight section which enters the wheel chamber. A closer inspection of the underground part of the race is needed to ascertain if any early 19th-century features survive. Its circuitous route may have been determined by the early 19th-century building layout. A cursory inspection of the headrace tunnel from inside the wheel chamber has revealed a low brick arch some distance upstream of the chamber, possibly the side of a former bridge, and suggests that its route may have been altered later in the 19th century.

Downstream of the wheel chamber, the tailrace tunnel is intact and seems to be in the same position as the tailrace shown on the early to late 19th-century maps. It comprises a brick segmental-arched vault on low walls. The downstream end of the tunnel was partially blocked during recent engineering works, although at the upstream end of the site the entrance to the leat is still open to the river channel.

The water wheel

The wheel shaft and north-end shroud are still *in situ* in the wheel pit. Most of the wheel's middle ring also survives, now abandoned in the pit, which together with other fragmentary remains enables a virtual reconstruction of most of the former wheel. The missing south shroud included the ring gear which drove the power transmission into the works, but the former position of the main pinion drive shaft is indicated by its bearing plate. A later ring gear has been added to the *in situ* north shroud. The wheel was of the high breast-shot suspension type that was commonly used in large textile mills in the early to mid-19th century. Suspension wheels were introduced in the late 18th century and were developed in the early to mid-19th century by William Fairbairn and others. They embodied a range of improvements over traditional types of wooden or composite wheels based on a better understanding of waterwheel engineering, and utilised prefabricated cast- and

wrought-iron components. At suitable sites they continued to be used, with minor improvements to the design, up to the late 19th century, but thereafter were increasingly replaced by turbines or alternative sources of power (Figure 35).

The wheel shaft is an assembly of five parts, comprising the main shaft casting, the two bolted-on end castings incorporating the journals and the two separate hubs that are fixed onto the end castings with metal wedges (Figure 36). The main shaft casting is 2.77 metres long (just over 9 feet) and 38.2 centimetres in diameter (15 inches) with eight radial ribs that are deeper towards the outer ends. The end castings are reinforced with four deeper triangular ribs and include an octagonal section with flat faces for the wedges used to attach the hubs. The wheel shaft bearings are fixed onto the sides of the wheel pit by long tie-bolts. Both are intact with brasses but no top caps; they incorporate holes used for jacking up the shaft to replace the brasses.[68] The separate hubs are complex hollow castings, 86.4 centimetres in diameter (17 inches). They have a wide outer flange containing cast-in holes that are positioned to accept the eight spokes supporting the shroud, and eight more that are angled at around 45 degrees to support the middle ring.

The shroud comprises eight segments, 45.7 centimetres (18 inches) deep and 1.2 centimetres (½ inch) thick, which are assembled with bolted lap joints. The middle of each segment is supported by a single spoke attached to a bracket cast onto its inside face which has a T-shaped housing. Curved flanges on the inside face of the shroud supported the ends of the buckets and the sole plate; each segment supported six buckets. Most of the bucket flanges were broken off the shroud during the partial dismantling of the wheel (Figure 37).

The middle ring comprised eight T-section segments which were bolted together using flitch plates. Its outer horizontal flange supported the wheel's sole plate and the central row of bucket stays (see below). The vertical flange of each segment has a cast-on angled projection with a T-shaped housing to accept the ends of the angled spokes (Figure 38).

The wrought-iron buckets do not survive intact but their shape is indicated by the flanges on the shrouds and sufficient fragments survive in the wheel pit to enable a reconstruction of their original form. The wheel had forty-eight buckets set about 34 centimetres (13 inches) apart at their outer ends. The bottom of the buckets was closed by a continuous sole plate. In cross-section, the outer one-third of the buckets was curved, in a profile similar to that used in other early to mid-19th-century suspension wheels.[69] The buckets and the sole plate were made from wrought-iron sheet about 3 millimetres (one eighth of an inch) thick. Between the shrouds the buckets were also supported by additional cast-iron bucket stays. Surviving fragments suggest that one set of stays was mounted on the middle ring with one more on each side, half way between the middle ring and the shrouds. The stays were a distinctive four-sided casting which was curved to match the circumference of the sole plate and the profile of the buckets. Projecting flanges enabled them to be bolted together through the buckets to form a continuous ring around the circumference of the wheel. The central stays had additional flanges in the base for bolting onto the middle ring.

In the north-west corner of the wheel pit, curved scrape marks suggest that the wheel or ring gear has been altered. The marks are behind the shroud and only partly visible, but can be seen to follow

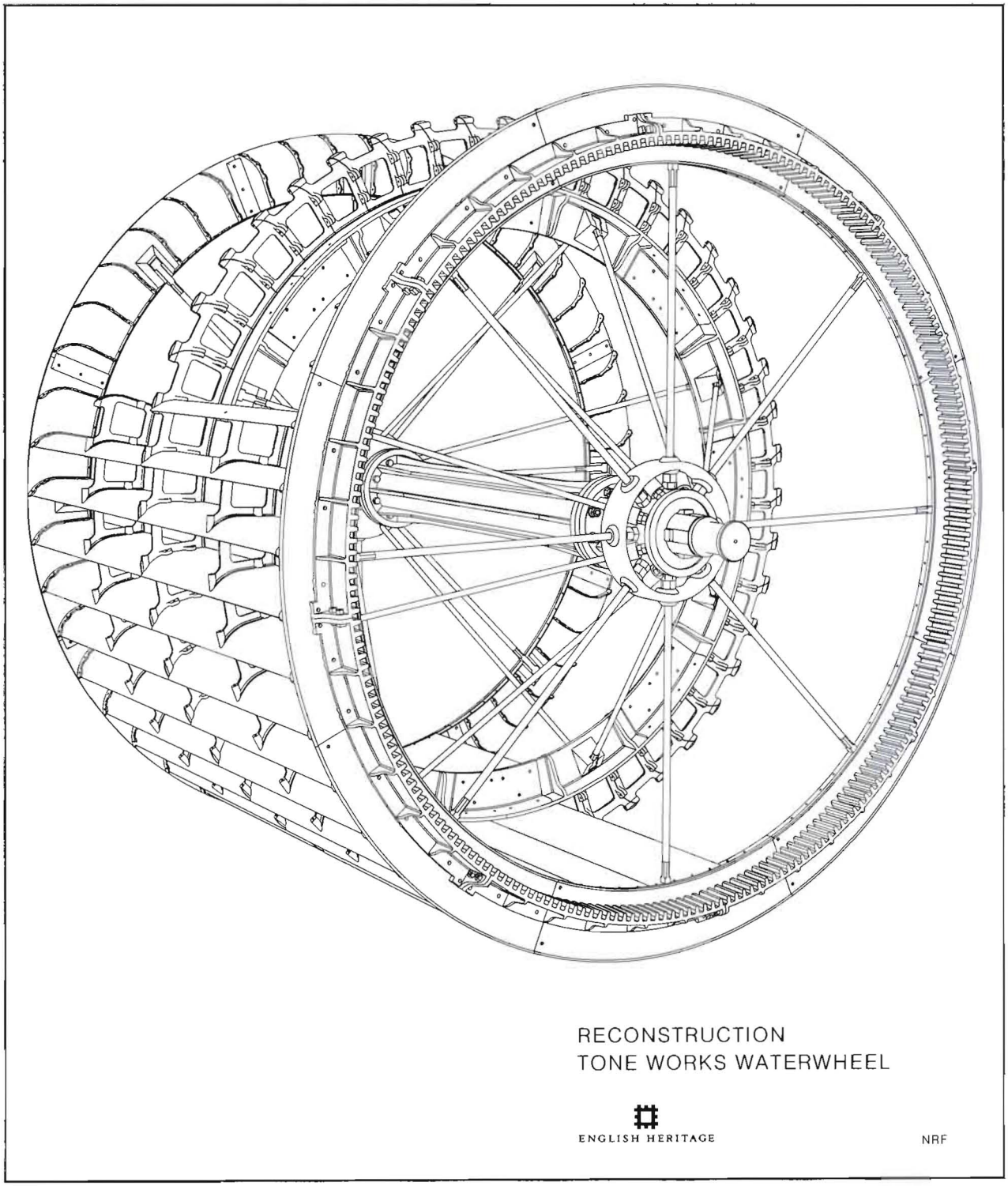


Figure 35.
Reconstruction of the Water Wheel, surveyed April 2007.

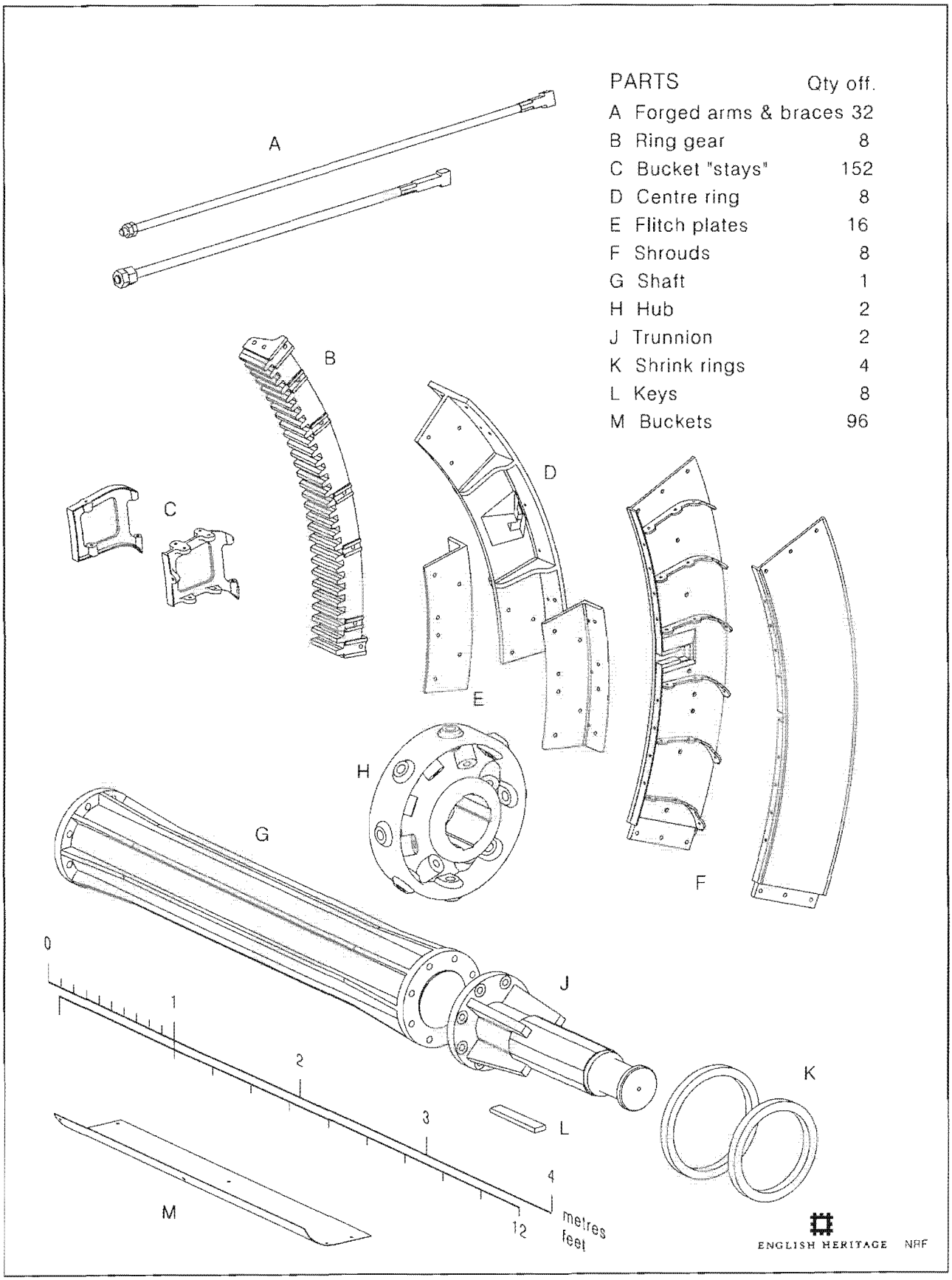


Figure 36.
Water wheel details, surveyed April 2007.

Figure 37.
The surviving north shroud of the water wheel.
[AA96/00680]

Figure 38.
The partially-dismantled middle ring in the wheel pit.
[AA96/00684]

the radius of the breastwork on the south face of the raised stone block that supports the penstock. They could not have been made by the nearby shroud, but could relate to the presence of an earlier ring gear on an earlier shroud of slightly smaller diameter.

A carefully-designed penstock to regulate the flow of water into the buckets was integral to the concept of the suspension wheel. The Tone Works penstock is well-preserved, retaining most of its mechanical components, although the moveable shutter is currently fixed in the closed position. It comprises a cast-iron frame spanning the full width of the headrace which supports the shutter mechanism and directs the flow of water accurately into the buckets of the wheel. The whole structure is bolted to large ashlar blocks on each side of the headrace at the higher upstream end of the wheel house (Figure 33, above).

The frame of the penstock consists of a top plate spanning the full-width of the race which is bolted to vertical end plates and a vertical central plate. The front edges of the vertical plates are curved to closely match the shape of the waterwheel, the curve having a radius about one centimetre greater than that of the wheel shroud. Between the vertical plates are six horizontal slats, or guide plates, which are set at predetermined angles to direct the water efficiently into the buckets. The angle of the slats directs the water into the bottom of the bucket and prevents it from hitting the sole plate or the back of the preceding bucket. The lower slats are set at a steeper angle to match the changing angle of the buckets as the wheel rotates.

The shutter is heavily constructed of 8.2 centimetres thick (3¼ inches) timber in a cast-iron frame. In common with the shutters of other suspension wheels, it is designed to open by sliding downwards into a slot behind the breastwork of the pit. The water entering the wheel flows over the top of the

shutter, thus maximising its fall; a conventional sluice is raised to allow the water to flow underneath. The shutter has wheels on its upstream face which run along a pair of vertical tracks bolted to the penstock, and also slides along guide ribs cast onto the vertical end plates. It was held in position on the tracks and the guides by the pressure of water in the headrace. The slot for the shutter under the floor of the race is clogged with mud, but its position is marked by a 96 centimetres (3 feet 2 inches) high band of cement above the ashlar breastwork of the wheel pit. The weight of the shutter was balanced by a pair of counterweights suspended in the headrace. These were connected to the shutter by chains running over pulleys mounted on wooden frames above the penstock. Most of the counterweight system survives but is partially dismantled.

The 1893-5 alterations enabled the penstock to be controlled from outside the wheel chamber. The shutter control mechanism remains *in situ*, comprising a pair of toothed racks mounted on its upper edge, which are raised and lowered by pinions on a shaft running the full width of the top plate. The pinion shaft extends beyond the south end of the penstock to the side of the wheel chamber, where it is turned by a large worm gear. The worm was operated by a long angled shaft running eastwards to a pair of bevel gears, which were connected to a control wheel on the outside wall of the wheel chamber. The parts of the shutter mechanism that are attached to the penstock may pre-date the 1893-5 alterations.

There is tentative evidence that a debris screen was formerly suspended in the headrace immediately upstream of the penstock. The west end wall of the wheel chamber has horizontal recesses and nearby projecting brackets on its inside face indicating that a horizontal shaft formerly spanned the blocked opening above the headrace. This appears to have been used to lower a piece of equipment into the race. Screens or gratings of vertical iron bars were commonly used to prevent floating debris from becoming jammed between the wheel and the closely-fitting breastwork.

Power transmission from the wheel chamber

The 1893-5 power transmission is mostly intact in a gear pit adjoining the south side of the wheel chamber, but there is also evidence of an earlier transmission on the south side of the wheel and another on the north side. The original main transmission would have been on the south side, where the early 19th-century works was located, and would have comprised a ring gear attached to the south shroud driving a pinion shaft. The former position of a ring gear on this side of the wheel is confirmed by the survival of the plate to support the pinion shaft bearing.

The gear pit is constructed in red brick beneath the Finishing Shed floor and is covered by heavy steel plates (Figure 32, above). It is T-shaped in plan, comprising a deeper rectangular section alongside the wheel-chamber wall with a shallower square section adjoining its south side. The deeper section contains the 1893-5 main belt drum and spur gears, but may have been re-used from an earlier power transmission. Its east end has curved breastwork suggesting that it may have been built to accommodate an earlier large gear wheel on a pinion shaft. Its floor is currently obscured by a deep layer of mud, but at the west end the tops of a pair of cast-iron shaft boxes are exposed, each about three feet wide. These may have supported the bearings of a horizontal main shaft driven by spur gears from the pinion shaft.

Figure 39.
The ring gear added to the north shroud. The base plate of a former pinion shaft bearing remains in situ *on the edge of the wheel pit. [AA96/00683]*

An intact ring gear is bolted to the north shroud, and was associated with the use of power to the north of the wheel chamber in the mid- or late 19th century. The shroud casting did not include any flanges to support a ring gear, indicating that the ring was a later addition. The ring gear casting appears to be of mid- or late 19th-century date and its teeth are heavily worn, indicating that it was in use for some time (Figure 39). No clear documentary evidence has been found for a large powered building to the north of the wheel chamber, however, suggesting that the power was used for a minor ancillary process.[70] The present north wall of the wheel chamber is itself a later addition, probably contemporary with the Finishing Shed, and replaced any further evidence of the power transmission or adjoining buildings.

The 1893-5 power transmission comprised a belt-drive system for the Finishing Shed driven by spur gears from the ring gear and pinion at the south end of the water wheel (Figure 32, above). It survives intact except for the pinion gear and the drive belt. The pinion shaft is 15.8 centimetres (6¼ inches) in diameter and supported by massive bearings located in a shaft box in the south wall of the wheel chamber and on a large cast-iron bracket in the gear pit (Figure 40). An additional bearing may have formerly supported the shaft close to the pinion wheel at

Figure 40.
Detail of the gear chamber, showing the main spur gear mounted on the pinion shaft. [DP046036]

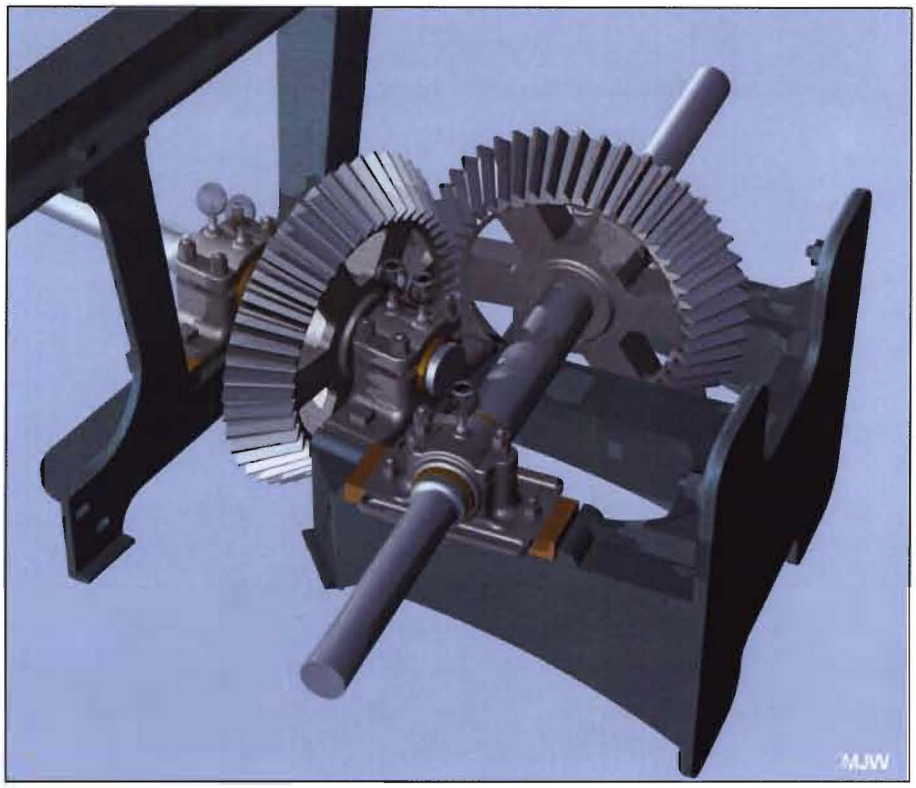
its north end; the base plate of a bearing survives in this position on the south walkway of the wheel chamber, although it is not clear whether it was part of the 1893-5 alterations or survives from an earlier power system. A large gear wheel, 2.47 metres (just over 8 feet) in diameter with 120 teeth, is mounted on the pinion shaft in the gear pit. It drives a smaller gear, 8.54 metres (2 feet 10 inches) in diameter with 40 teeth, which is mounted on the shaft of the main belt drum. This shaft is located at a higher level in the west end of the gear pit, where it is supported by similar bearings to the pinion shaft. The belt drum itself is 2.73 metres (just under 9 feet) in diameter by 64 centimetres (2 feet 1 inch) wide and extended above ground-floor level, where it is now concealed behind a fixed wooden box. It aligns with a smaller belt drum, 1.13 metres (3 feet 8½ inches) in diameter, which remains attached to the section of line shaft above the wheel chamber. The gear wheels and the belt drums served to increase the rotational speed of the line shafting up to that required in the Finishing Works.

There is good evidence that the 1893-5 power transmission was designed to enable the Finishing Shed and parts of the Dye Works to be driven by the combined use of steam and water power. The water-powered line shaft above the wheel chamber extends northwards into the Finishing Shed and southwards into the Dye Works (Figure 29, above). This shaft is parallel to the wheel shaft and therefore square to the wheel chamber. The steam-powered line shafts, and the Finishing Shed itself, are all built square to the engine house at the west end. The two sets of shafting meet at an angle of about 78 degrees with a pair of bevel gears on the shed's main drive shaft attached to the north side wall (Figure 41 a & b). The brackets supporting the water-powered shaft, the bevel gear brackets and the teeth of the gears themselves have been specially made to enable the two sets of shafting to meet at this angle. The water-powered shaft incorporated a friction clutch, which remains *in situ* above the north wall of the wheel chamber, which enabled the two power sources to be combined while the shafting was still in motion (Figures 42 and 54).

The Dye Works

The interior of the Dye Works has not been accessible for recording; the following initial assessment of its development is based on external evidence, photographs and available documents. It comprises three groups of attached late 19th-century buildings located to the south of the wheel chamber, and one other located across the yard, with good evidence of the survival of some early 19th-century structures (Figure 24, above). The 'front' of the Dye Works is a group of one- and two-storeyed gabled buildings on the east side of the yard; these include a re-set 18th-century date stone, and appear to be a reconstruction of earlier buildings in the same position. Adjoining to the east is a group of single-storeyed gabled buildings with prominent rooftop ventilation louvres. The third group comprises north-light sheds that were added to the south in at least three phases.

The buildings facing the yard (buildings 13 - 15 on the block plan; Figure 10, above) comprise a two-and-a-half-storeyed building with a wide-gabled roof and a narrower two-storeyed gabled building attached to its south side (Figure 43). The larger building has three bays of segmental-headed windows and a double-width door, while the narrower building has a single round-headed door with a round-headed window above. The fenestration and proportions are



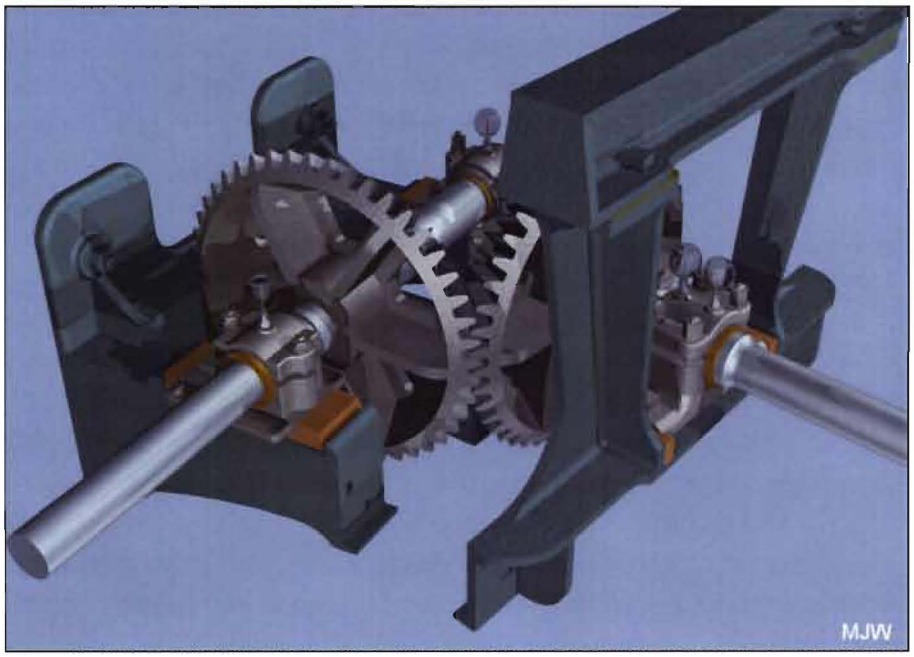


Figure 41 a & b.
Two views of the main bevel gear assembly in the Finishing Shed, surveyed April 2007.
[drawing 6 of 8]

Figure 42.
The friction clutch is still attached to the water-powered shaft above the wheel chamber. [DP043906]

Figure 43.
The front elevation of the Dye Works was rebuilt in the late 19th century, but incorporated a re-set 18th-century date stone. [BB96101702]

different to those shown on the c1886 letter head, and the absence of a straight joint suggests that both structures were re-fronted at the same time. The whole elevation is of squared grey rubble with red brick jambs and heads; the materials, fenestration and roof details all suggest a late 19th-century date. The larger building has a circular opening for a clock in the gable[71] and the smaller building has a re-set 18th-century date stone, suggesting that this was perceived to be the front of the works. Exposed parts of the roof have timber queen-strut trusses which also appear to be of late 19th-century date.

Similarities between the layout of this area and that shown in mid- to late 19th-century documents suggest that these buildings are a partial reconstruction of the early 19th-century site. Further evidence that the yard elevation is a late 19th-century rebuilding survives in the north-east corner of building 15, visible from inside building 16. This area is built of coursed rubble with vertical tooling that distinguishes it from the stonework used in the yard, and appears to be part of an earlier phase of building. The corner includes a blocked door into building 15 and adjoins parts of other earlier walls to the north and east. It is shown on the Wellington Tithe Map as the external junction of two of the early buildings. An internal inspection of the extant Dye Works should aim to identify any other sections of similar early stonework.

The upper floor and roof space of building 15 is occupied by a large cast-iron tank supported by a combination of cast-iron columns and doubled timber beams. The tank initially contained treated water for the Dye Works but was later converted into an oil tank.[72] The ends of the massive supporting beams are exposed in the north side of building 15, which is visible in building 17a. This wall contains evidence of several phases of rebuilding in stone and brick, including some rubble areas which seem to pre-date the yard elevations. It also contains a large blocked shaft box, probably for a main drive shaft, just above the present ground level. Late 19th-century documents refer to an engine in the Dye Works but do not indicate its position. The narrow plan of building 14, which is in-line with the blocked shaft box, suggests that it could have accommodated a beam engine or a tandem horizontal engine before the first floor was inserted and the yard elevation rebuilt (this requires on-site investigation – see Recommendations for Further Research).

The second group of Dye Works buildings, adjoining to the east, are single-storeyed with separate gabled roofs and external elevations, facing the river, of conglomerate rubble and red brick. The eastern elevation is currently overgrown, but variations in the stonework suggest several phases of repairs and extensions (Figure 44). The largest phase is roughly parallel with the river on a north-south axis. Its north end seems to be close to the position of a similar building on the Wellington Tithe Map, but appears to have been extended to the south (this requires on-site investigation). A red brick infill section in the east elevation may indicate the position of the south end of the structure shown on the Wellington Tithe Map; the brick section is of mid- to late 19th-century date, but contains a large opening behind a wooden panel that was added in the late 1990s. An additional phase of rubble wall adjoins it to the south. These buildings all have similar tall gabled roofs with prominent ventilation louvres; internal photographs show a complex arrangement of heavily-built queen-post trusses in this area (Figure 45). Similar roofs, but oriented east-west, are attached to the west, giving this part of the site a highly distinctive roof structure. The engraving on the c1886 letter head shows similar roofs but without the louvers; it also shows two nearby chimneys, suggesting

that boilers were sited nearby. These buildings were clearly used for heated processes in the late 19th century, and their early date and proximity to boilers suggests that they may be the modified remains of the first purpose-built buildings for dyeing. The earliest available documentary reference to a separate dye house is dated 1846.[73]

Figure 44.
East elevation of the Dye Works in 1995.
[AA96/00698]

Figure 45.
Heavily-built ventilated roofs and multiple phases of wall construction in the eastern part of the Dye Works. [AA96/00711]

The last extensions to the Dye Works were the north-light sheds that now form the south and west elevations (buildings 8-10). These buildings still retain many of the later dye vats and related machinery. They are of similar rubble and red brick detailing to the gabled buildings in the yard, but with segmental-headed recessed panels and circular brick ventilators to the external elevations. The north-light roof had additional conical metal ventilators up to the mid-1990s. The sheds were built in at least two phases, and were probably re-roofed later. The c1886 letter head shows a smaller shed with four north lights occupying the south-west corner, but the 1889-90 O.S. plan shows one structure covering the whole of the south end of the site. This suggests that the earlier smaller shed was either rebuilt or extended to the east and north around 1890. The position of the south-east corner of the earlier shed is indicated by a pilaster alongside a sharp change in the angle of the south elevation overlooking the river.

In the north-east corner of the Dye Works area, buildings 16 and 16a were probably rebuilt at about the same time the north-light sheds (buildings 8-10) were being completed to the south. The eastern elevation of these buildings is of similar rubble and red brick to the sheds and has four bays of similar recessed panels. In this case the panels are arranged in two rows to create the impression of a two-storeyed building. Behind the façade, however, this area comprises a tall single storey. It was re-roofed by a continuation of the Finishing Shed roof in 1893-5 and no evidence survives of a former first floor.

The Streaming Shop

This is a small single-storeyed late 19th-century building, on the east side of the yard, which was functionally linked with the Dye Works (Figure 29; building 21 on the block plan, Figure 10). It is built directly above the headrace to a wide rectangular plan, with a north-light roof, and is shown on the 1889-90 OS plan and the c1886 letter head. The walls are of grey rubble with red brick details similar to the south-west part of the Dye Works, and both buildings have identical moulded stone kneelers to the corners of the roof (Figure 46). This suggests that the Streaming Shop and the south-west part of the sheds were built at about the same time as part of a general expansion of the Dye Works. A small red-brick workshop was later added to the south end of the Streaming Shop, probably in the 1890s. The north-light roof comprises timber trusses and valley gutters supported by timber tie-beams and cast-iron columns. The floor was open to the race, which was used to rinse out surplus dyes from the cloth.[74] Cloth pieces were placed in metal baskets that were rotated on frames fixed in the flowing water of the race; parts of the frames are still visible. This was especially important for the finishing of dark cloths, for which the firm was well known, before the development of dyeing techniques that properly fixed the colours. A later concrete floor on rolled-steel beams has been inserted in the centre and across the south side of the building, but the areas by the west and east end walls are still open to the race. The original floors, which were presumably wooden with opening traps, were supported on wide-arched brick sleeper walls which remain exposed adjacent to the end walls. Redundant corbels and blocked shaft boxes in the south and west walls suggest that powered shafting was originally used in the building. A later generation of inserted bearing boxes for a main central line shaft and smaller boxes for parallel shafts above the exposed parts of the race indicate that power continued to be used after the present floor was constructed, possibly for hoisting the cloth baskets or some kind of washing process in the flowing water.

The floor of the Streaming Shop also contains small sluice gates adjacent to the south and east walls that were used to divert water from the race into an effluent tank beneath building 16. The 1889-90 OS plan shows a curved structure projecting from the west elevation above the head race, presumably a debris screen. A similar screen remains *in situ* at Coldharbour Mill. A covered wooden footbridge is now attached to this elevation. This was added in the 1890s to give external access to the new engine house of the Finishing Works.

The detached Boiler House

The boiler house to the west of the Dye Works was built in 1884-5, partly on the old course of the river, when it replaced an earlier boiler house on the site of the sheds added to the south of the Dye Works. It is shown on the c1886 letter head along with a tall free-standing chimney on the river bank to the south east. It was part of a major reorganisation of the steam plant at both Tone Works and Tonedale Mills, and was said to have been 'working splendidly' with a new economiser in 1885.[75] The building had ceased to be used for its original purpose by c1930, by which time the chimney had been demolished. From c1922 steam for Tone Works was provided by the boilers of the new Power House (see below).

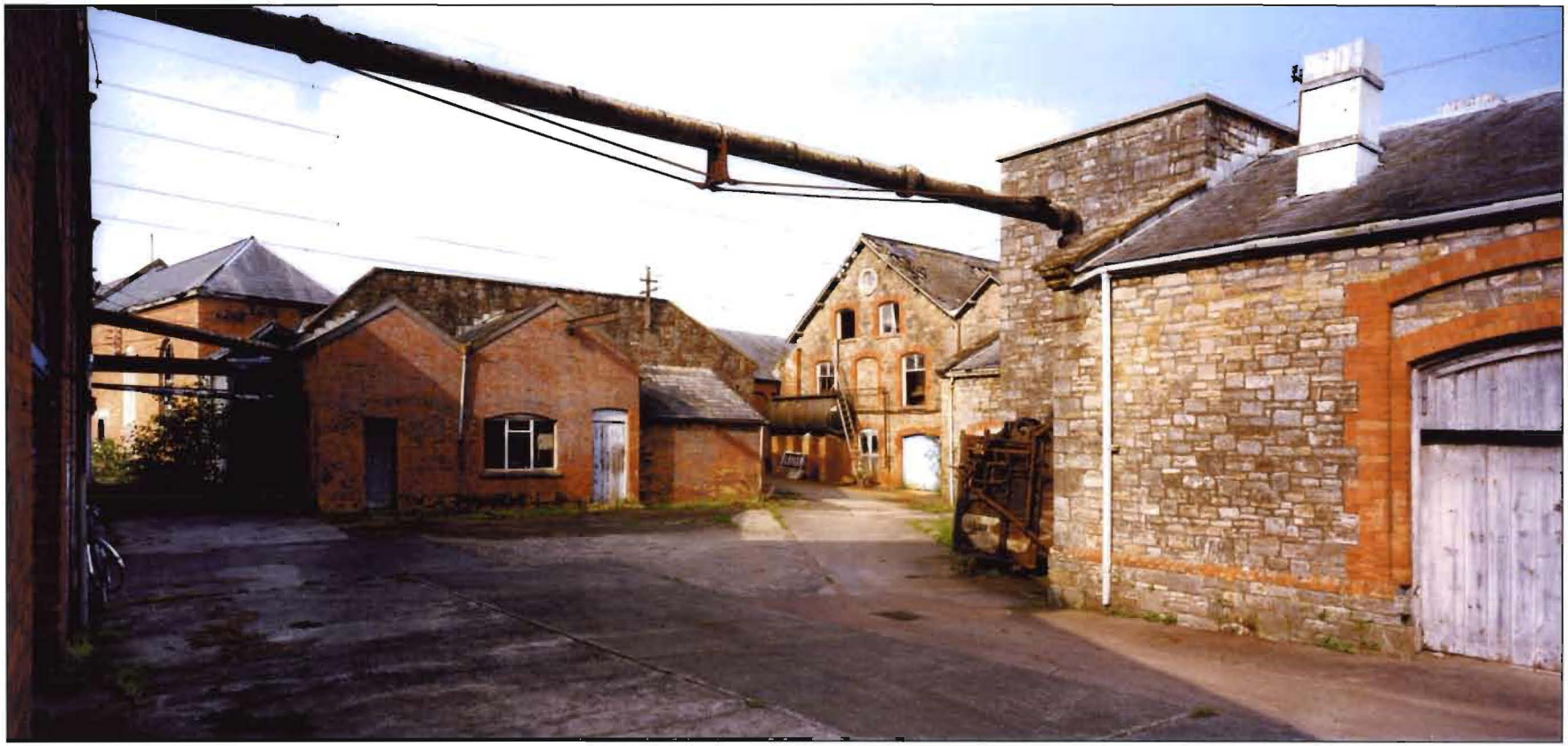


Figure 46.
The yard to the west of the Dye Works, with the Streaming Shop in the centre. [BB96/01678]

It is a tall single-storeyed building in red factory brick built to a roughly square plan with a triple-span roof (Figure 47). The roof originally comprised three symmetrical east-west ridges, but the central ridge was later replaced with north-light trusses and its gable end partly rebuilt. The front, east, elevation has a wide-arched opening beneath each of the gables. An original lean-to extension is attached to the south side, with a round-headed door matching the form of the other doors facing the yard. In 1995 a sign on the wall indicated that this was a disused fire station. An extension on the west side is of similar proportions, but replaces an earlier narrower extension shown on the 1904 OS plan. A third lightly-built extension, with a corrugated asbestos roof, was added to the north side, above the open head race, sometime after 1930.

Figure 47.
The 1884-5 Boiler House. [AA96/00730]

Internally the building comprises a single open space with a concrete slab floor and very little evidence of the former boilers (Figure 48). The outer aisles of the roof retain their original structure, comprising lightweight iron or steel principals, trussed with parallel tension rods and horizontal and vertical tie-rods. L-section common rafters support wooden laths. Similar roofs were built at this time on a new boiler house and other extensions at Tonedale Mills. The principals are mounted on moulded stone corbels; redundant corbels in the central aisle confirm that it formerly had the same type of roof. The absence of rooftop

Figure 48.
Interior of the 1884-5 Boiler House in 1995. [BB96/01707]

ventilation is unusual for a purpose-built boiler house of this date, although this may have been removed when the central roof span was replaced.

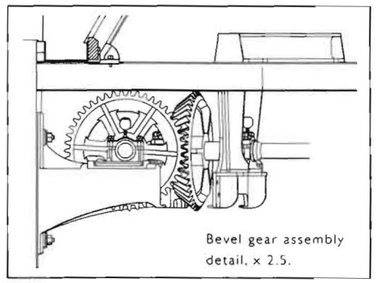
The Boiler House is sub-divided into three east-west aisles by a pair of arcaded walls. The walls each contain three arched openings, and also support the valley gutters. The original boiler layout is not known. It seems likely that each aisle contained a single large Lancashire boiler with the firing floors at the east end, although smaller boilers could have been installed in a north-south layout to either side of the arcaded walls. The site of the detached chimney to the south is now a bramble patch, but the top of the underground brick flue leading to it is still visible. The economiser was probably located either at the back of the boiler house or in the west extension. In the 1990s the west extension contained the Permutit water-softening plant which was purchased in the late 1920s.

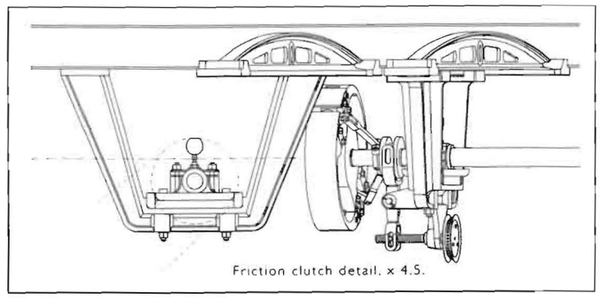
The 1893-5 Finishing Works and Machinery

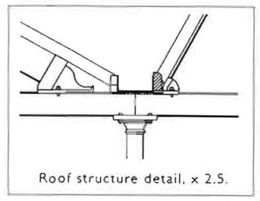
The Finishing Works was built on the site of an open yard or roadway between the Dye Works and the North Dry House (Figure 29, above). As the largest building at Tone Works its construction marked a reorganisation of the whole site, with increased emphasis on cloth finishing and more segregation of the finishing and dyeing processes. Most of the remaining early buildings were demolished except for the wheel chamber and the eastern half of the North Dry House, both of which were retained but modified (Figure 49). The adjoining Streaming House was also retained. The Finishing Works was conceived as a largely self-contained factory with its own combined power system, process-water management system and a more efficiently-organised arrangement of processes than was possible in the older complex of small attached buildings. It comprised the new Finishing Shed itself with the Engine House and Motor Room attached to the west end, but also involved extensive alterations to other parts of the site. In particular, the new ponds and water-treatment facilities were built at the same time primarily to supply the Finishing Works with large quantities of softened water.[76]

The Finishing Shed

The Finishing Shed is significant as one of the best-preserved 19th-century north-light shed factories in the country (Figure 50). As a building type, north-light sheds first appeared in the 1830s for power loom weaving and were later used for spinning, carding and cloth-finishing processes, as well as a range of other industries. From the 1860s single-storeyed factories were promoted as the most efficient type, and in the early 20th century they eventually replaced multi-storeyed buildings, especially in new industries such as motor manufacturing. The north-light shed was therefore one of the progenitors of the 20th-century factory. Its structure provided exceptionally good interior lighting but also allowed flexibility in the organisation of machinery and, importantly, an efficient means of supporting the line shafting of a power-transmission system. In the 19th century north-light sheds were built in huge numbers in the industrial regions, but by the late 20th century demolition was widespread and very few well-preserved examples survive. The Tone Works Finishing Shed is now one of only two intact 19th-century north-light sheds that are known to survive with the original power transmission system and the original type of machinery.[77] There are no other known examples with a combined steam- and water-power system or an intact early electric power system.







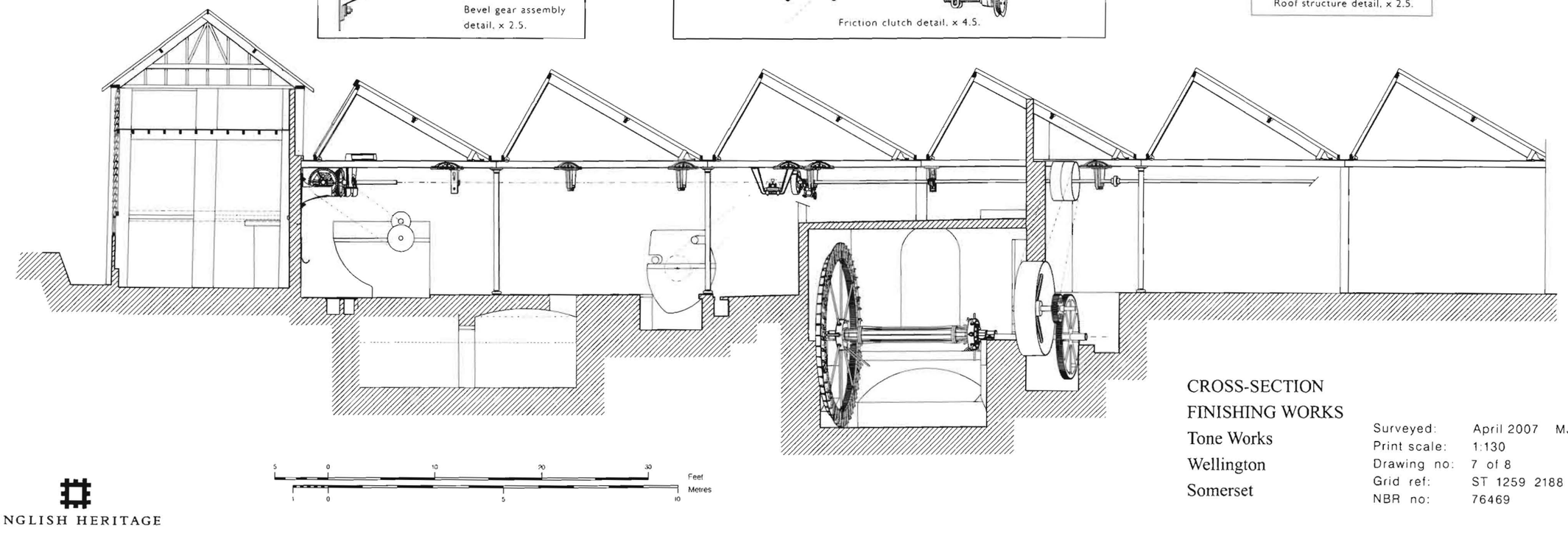


Figure 49. *Cross-section of the Finishing Works, surveyed April 2007*

Figure 50.
Interior of the Finishing Shed with working scouring machines, 1995. [BB96/01685]

The external elevations of the shed, Engine House, Motor Room and the rebuilt west half of the North Dry House are all of the same factory-made red brick. The shed's east wall and the short section of north wall adjoining the end of the dry house have tall recessed panels with segmental heads to each bay and a level parapet with a plain stone coping. Additional internal brick walls were inserted in the southern part of the shed in the early 20th century. The 1904 OS plan shows internal walls adjoining the wheel chamber which are not aligned with the shed and may have been retained from the earlier buildings. The shed wall at the north end of the yard is also shown in a different position to the extant wall. These walls are not shown on the 1930 OS plan. They were replaced with lightly-built brick partitions which are aligned with the shed and contain wide segmental-headed windows (most now blocked), creating rooms 17a and 16a on the block plan (Figure 10, above). The original north-light roof of the shed and its concrete floor continue through these rooms, confirming that the walls were a later addition. These inserted walls are an indication of the further segregation of processes in the Finishing Works; processes such as raising and shearing benefit from a drier atmosphere than the humid conditions found in the scouring and milling areas. The present shed wall at the north end of the yard, containing the main double doorway, is probably contemporary with the inserted walls.

The shed roof was assembled from prefabricated components that were typical of the mid-1890s, comprising a timber north-light roof mounted on rolled-steel tie-beams and cast-iron valley gutters that are supported by cast-iron columns (Figure 49, above). The principals, rafters, purlins, ridge pieces, window frames and internal cladding are all of timber. The principals are supported by cast-iron brackets that are bolted onto the tie-beams and the common rafters are mounted on housings cast onto the sides of the valley gutters. The single rank of purlins is attached to the principals with wrought-iron straps. The columns have typical embellishment for the 1890s, with a torus at the base and another above an embossed ring at the capital. They have a cast-in square base plate, mounted on a stone pad, and a rectangular top plate with raised edges to locate the tie-beams. They are 15 centimetres (6 inches) diameter at mid-height and 3.65 metres (just under 12 feet) high, and are positioned at the intersections of the tie-beams with the valley gutters in each bay, at an average east-west spacing of 3.3 metres (10 feet 11 inches). The valley gutters are 31 centimetres wide (12 inches) by about 15 centimetres (6 inches) deep and assembled from sections bolted together at the tie-beams. They are set at an average north-south spacing of 6.1 metres (20 feet). The I-section steel tie-beams are 20 centimetres (8 inches) deep; the beams which were intended to support line shafting have 15 centimetre (6 inch) flanges, and the others all have 10 centimetre (4 inch) flanges.

The cast-iron components are attached to the steel tie-beams using forged L-shaped bolts. These are clamped to the edges of the flanges, presumably to avoid drilling holes through the steel. The tie-beams themselves, most of which are the length of a single bay, are not joined with bolts but clamped onto the column top plates using similar L-bolts. The same system is used for attaching the cast-iron brackets supporting the roof trusses and the various beams and brackets that support the line shafting; in this case the brackets are attached *beneath* the soffits of the tie-beams, the entire weight of the line shaft assembly being supported on the L-bolts.

The concrete floor of the shed was built above the former ground level as a flood prevention measure. It is reached from the yard by a concrete ramp and from the road alongside the east wall

by a sunken loading bay. It forms the roof of the head race, in which the concrete is supported by a ceiling of transverse brick vaults and steel beams, and also contains several large structures associated with the water management system. Several open and covered channels were built into the floor to convey effluent away from the machines, and originally contained cast-iron pipes which supplied treated water to the machines from the nearby storage tank. The largest features are two longitudinal open channels, each about two metres wide and one metre deep, located beneath the first and third roof bays from the north side; the main rows of scouring and milling machines are sited above these channels. Narrower covered channels are located along the outer edges of the main channels, and a third narrow channel runs in a perpendicular north-south direction near the east end. This channel enters an effluent tank beneath the floor of building 16, from where it was pumped in pipes across the Rover Tone for treatment in the Grease Works. It is not known whether additional effluent channels exist in the Dye Works. Another substantial feature of the Finishing Works is a large underground reservoir or tank, of unknown function, which lies beneath most of the eastern half of the shed. This is 2.7 metres (8.feet 9 inches) deep, containing 1.3 metres (4 feet 4 inches) of water, and about 6.2 metres wide (20 feet 4 inches) at its west end. It comprises two parallel chambers with brick vaulted ceilings, but is not oriented square to the shed walls, suggesting that it may be the remains of an earlier feature.

The different types of channels are original features connected with the supply of process water and removal of effluent, although their exact functions are also not known. They are associated with a complex arrangement of cast-iron pipes, valves and pumps which extends around most of the site, linking the ponds with the water treatment facilities, the boiler houses and the finishing and dyeing areas. The original storage tank for softened water for the Finishing Shed was in the rebuilt west end of the North Dry House; this is now disused but the remains of pipes connecting it with the channels beneath the machines can still be seen. The scouring machines also needed a supply of hot water, which was supplied from the detached boiler houses in the overhead pipes which still cross the river from the 1922 Power House and cross the yard from the late 19th-century Boiler House.

The steam and electric power systems

The Engine House and Motor Room are attached to the west end of the Finishing Shed, forming a continuous elevation above the pond with the Engine House to the south (Figure 29, above). Both are tall single-storeyed buildings with gabled slate roofs of consistent height. The north end of the engine house is marked externally by a straight joint in the west elevation, although this does not indicate a change of building phase. Its west elevation has two tall arched windows and a low square box close to the north end, which contained the bearing of the engine's flywheel shaft. The Motor Room has a door next to the Engine House, which gives access to an elevated walkway leading to the nearby water softening towers, and five bays of segmental-headed windows arranged in two rows to create the appearance of two storeys. Internally the building is open from the ground floor to the roof trusses.

The proportions of the Engine House indicate that it probably contained a tandem horizontal engine, a type commonly used in late 19th-century textile mills. The concrete and stone beds of the engine are exposed in the floor, including sawn-off bolts near its south end, possibly for a floor-mounted

condenser. The building retains much of its original ornamentation, with glazed tiles beneath a dado, some of the floor tiles and splayed window bays with a beaded edge moulding (Figure 51). The original roof is probably intact above an inserted ceiling. The rectangular engine beds are intact beneath the floor, with the remains of tie-down bolts for the flywheel shaft and the other main components. A small pump is still attached to the beds under the position of the flywheel shaft and appears to be original. The area to the west of the beds contains a rectangular platform supporting a bank of metal boxes of unknown function, possibly part of a DC electric system.

Figure 51.
The Finishing Works Engine House. [AA96100653]

The Motor Room contains the two large DC electric motors that were purchased in 1922 (Figure 52), along with the massive cast-iron beams and bearings supporting the belt drive to the Finishing Shed's primary line shaft (see below). All the mechanical features of the 1893-5 steam power transmission system are *in situ* and pre-date the installation of the electric motors. The main drive belt originally passed from the engine's flywheel through two openings in the south end of the Motor Room, the lower opening being concealed beneath the step leading to the external door. The Motor Room was therefore far larger than was necessary for its original known function of supporting the main drive belt. Belt and rope-drive systems were commonly used at textile mills in this period but were usually accommodated in a much smaller belt race or rope race, often a narrow passage or a lightly-built external structure.

Figure 52.
One of the 1922 DC electric motors in the Motor Room. [DP043927]

There is tentative evidence that the Motor Room may have been originally designed to provide space for the installation of generators driven from the nearby engine. Fox Brothers were a progressive firm and it

seems likely that they had anticipated the use of electric power for machinery by the mid-1890s. Electric lighting was installed at Tone in 1893-4, although its location is not specified, and the first large electric motor was purchased in 1915.[78] A 1.2 metre (3 feet 11½ inch) diameter pulley for a drive belt is mounted on the main shaft in the north side of the room, and a lighter transverse line shaft remains *in situ* in the middle of the room; its end bearings are supported by heavy cast-iron brackets which appear to be original to the wall. These features indicate that a small machine, possibly a generator, was located inside the Motor Room and driven by steam power from the primary line shaft. Thus the Motor Room might actually have been built as a power house to provide DC electricity, initially for lighting. The available documentary evidence does not specify the original contents of the Motor Room, but it should be noted that 1893-5 would be an exceptionally early date for an intact electric power house.

The Finishing Works power transmission system

The power transmission system was unusually complex when built and is remarkably well-preserved, adding greatly to the historical significance of the site. Most of the mechanical components and their supports appeared to be in working condition when surveyed, providing a rare opportunity to examine intact late 19th-century line shafting. Only the main features are described here. The existing water-power facilities were adapted to be combined with the new steam-power system. DC electric power was added at an early date and eventually combined with AC power. The steam- and water-power systems had ceased to be used by 1947.[79] The modifications to the North Dry House included infilling the open panels between the piers along its south side to form a continuous wall for the Finishing Shed. The original brick piers still project slightly and were utilised to provide mounting points for the shed's tie-beams and line-shaft brackets.

The steam-power system comprised the engine, the main belt drive in the Motor Room, the primary line shaft attached to the north wall and the secondary line shaft in the third bay from the north side. Additional shorter line shafts were installed where needed and driven from either the primary or secondary shafts. Steam for the engine originally came from the detached late 19th-century Boiler House. The primary line shaft was powered from the engine via a 3.63 metre (11 feet 11 inch) belt pulley, which remains *in situ* in the Motor Room (Figure 53). The north end of the room contains heavy transverse and longitudinal cast-iron beams to support the primary line shaft, its bearings, the two attached belt pulleys and a clutch mechanism. The clutch is an

Figure 53.
The belt pulley driving the primary line shaft in the Motor Room. [AA96100677]

original feature which was positioned to disconnect the main section of the primary shaft from the short section within the Motor Room. The original purpose of the clutch is not clear, but it appears to have enabled the line shafting to be disconnected from the engine so that it could be driven solely by the water-powered shaft from the wheel chamber. The clutch has solid interlocking jaws (sometimes referred to as a dog clutch) which could only operate when the shaft was stationary. The operating mechanism was attached to the motor room wall but has been removed. In contrast, the friction clutch above the wheel chamber (described above) enabled the water power to be connected or disconnected while the shafting was in motion. In the second half of the 20th century the Motor Room clutch was also used to enable the line shafting to be driven from either the nearby DC motors or from the AC motors which by then had been installed in the Finishing Shed.[80]

The primary line shaft is 63.88 metres long (209 feet 7 inches), including the section inside the Motor Room, and is assembled from sections that are 6.7 metres (21 feet 11 inches) long. The sections are joined with bolted couplings. Inside the Motor Room it is 19 centimetres (7½ inches) in diameter, and in the Finishing Shed its diameter decreases from 13.3 centimetres (5¼ inches) at the west end to 7.6 centimetres (3 inches) at the east end; for most of its length the diameter reduces by 6 millimetres (¼ inche) at each coupling. The secondary line shaft is 56.1 metres long (183 feet 11 inches) and assembled from sections of the same length as the primary shaft but 8.9 centimetres (3½ inches) in diameter at the west end and 7.6 centimetres (3 inches) at the east end.

The line shafts are supported in bearings mounted on cast-iron brackets in each bay, both of which vary in size and details to suit the diameter of the shafting (Figure 54). The bearings themselves comprise a cast-iron base and separate cap enclosing the brass bushes. Most of the caps retain glass oil lubricators, and cast-on drip trays project from the sides of the bases. Additional light metal drip trays are suspended on wires beneath most of the bearings. The bearings supporting the thicker sections of shaft have wider caps with two oil lubricators; the largest bearings, supporting the clutch shaft in the Motor Room and the pinion shaft in the Gear Chamber, have caps with additional square grease boxes between the lubricators.

The brackets supporting the bearings are of two main types, which vary in size with the bearings. The primary shaft is supported by heavy L-shaped brackets bolted to the north wall and clamped to the tie-beams. The secondary shaft is supported by U-shaped hanger brackets clamped to the tie-beams. Similar hangers support the water-powered shaft and some of the shorter additional shafts. These are suspended from I-section cast-iron beams with convex webs that are clamped to the tie beams (Figure 54).

Power was transmitted between the line shafts using a combination of bevel gears and rope or belt pulleys. The primary shaft was the main source of power for the whole shed; it was directly driven by each of the three power sources, and it transmitted power to the adjacent row of machines and the other line shafts. The secondary shaft was later altered to be belt-driven from a floor-mounted AC motor, but machined key-slots in a thicker section near its west end indicate the position of a drive pulley that it was originally powered by a belt or rope from the primary shaft. The connection between the water-powered shaft from the wheel chamber and the primary shaft was achieved with a pair of 85.9 centimetres (2 feet 10 inches) diameter bevel gears supported by a massive

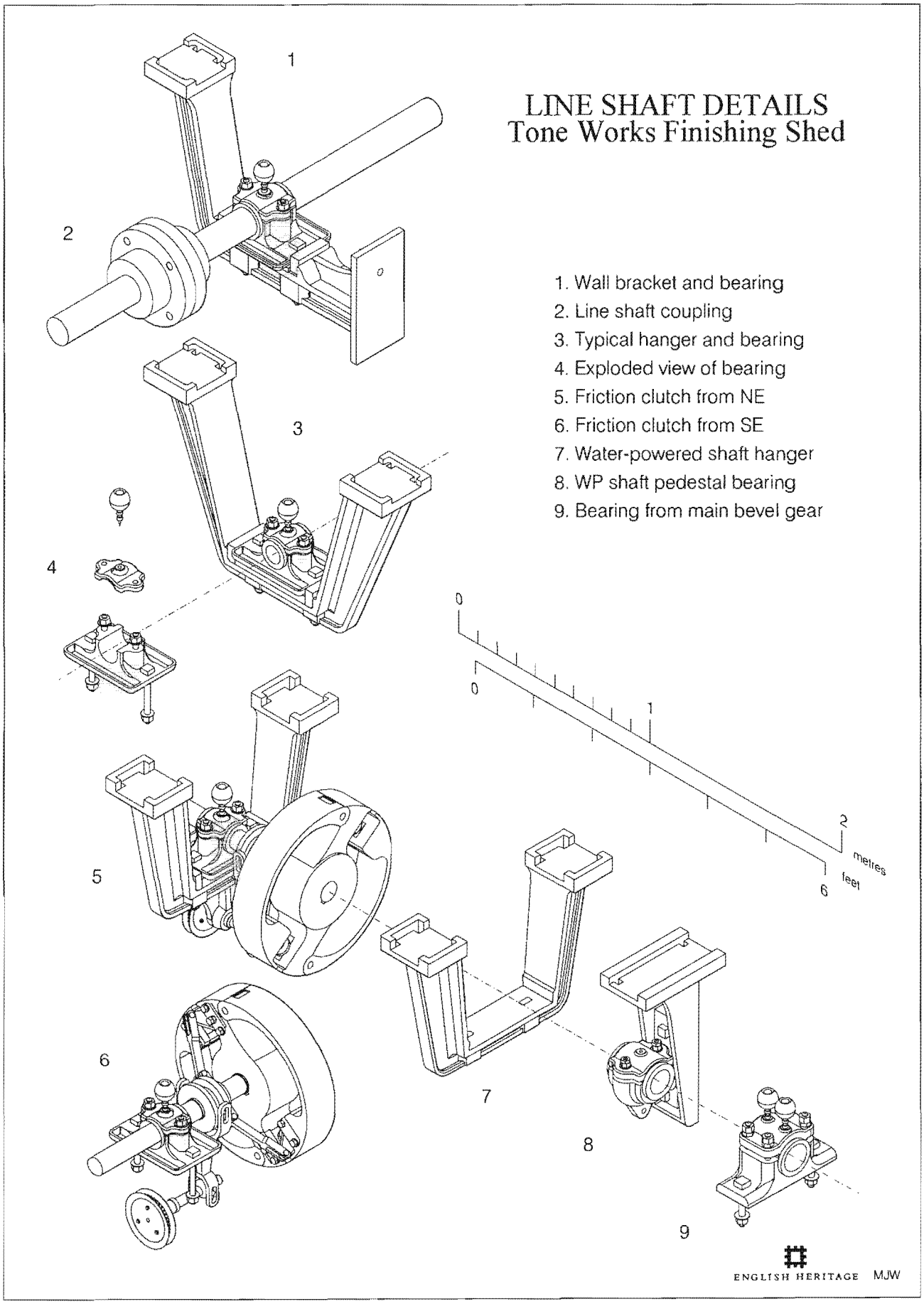


Figure 54.
Details of the line shafting in the Finishing Shed, surveyed April 2007.

cast-iron bracket bolted to the north wall, all of which remains *in situ*. The bevel gears were made specially for use in the shed, with the pitch circle of the teeth angled to match the converging angle of the two shafts (about 78 degrees; see Figure 41, above). The wall bracket supporting their bearings was cast with the bolting faces also set at the correct angle. The central part of the water-powered shaft has been cut-out, but the hangers and cast-iron beams which supported it are still *in situ*; these beams were also cast specifically for this position, with their end flanges correctly angled to overlap the flanges of the adjacent tie-beams. Similar methods were used to drive other shorter sections of line shafting. A second smaller pair of bevel gears was mounted on the secondary shaft to drive an additional line shaft running southwards into room 17a. In the north-east corner of the shed, another line shaft above a detached row of milling machines was rope or belt-driven from the primary shaft.

Finishing Works machinery

The extant machinery in the Finishing Works is not original to the building, having been repaired and replaced in the course of regular maintenance, but it is the original *type* of machinery and most of it is sited close to its original location. The machinery is thus entirely in-keeping with the historical significance of the site, and has been retained in working order because Fox Brothers specialised in high-quality cloths produced using traditional methods. This section describes the layout of the machinery; further details on the processes are given above, and photographs and brief descriptions of the individual machines are given in Appendix 3.

In the Finishing Shed the scouring and milling machines are arranged in two groups above the two drainage channels, while the cloth raising and shearing machines are located in separate rooms (Figure 29, above). Additional machinery used for handling of the cloth is strategically positioned around the shed. Various items of mobile equipment that were essential to cloth handling are also still in place.

The processes are arranged efficiently to allow the handling of the large pieces of cloth, which could be over 50 metres long, between the different machines. The layout is essentially the same as that shown in the 1912 photograph, and is notably more spacious than the machinery layouts of contemporary spinning or weaving mills. Scouring machines are located above the east and west ends of the south drainage channel, and at the west end of the north channel. The milling machines are grouped separately along the rest of the north channel and in a small alcove in the north-east corner. Milling machines are not sited above open channels, since the process did not involve large amounts of liquor, although the north channel is culverted beneath the main group. A smaller group of combined scouring and milling machines is located above the middle of the south channel (Figure 55). The location of the milling machines against the north side wall, beneath the primary line shaft, may be a reflection of the weight and vibration produced by the machines; their layout is comparable to that of traditional fulling mills, in which the fulling stocks were often sited against the back wall, alongside the main power shaft, for similar reasons.

The *in situ* scouring machines are arranged in two rows above the main drainage channels, and include a variety of examples installed to process different types of cloth (Figure 56). All show

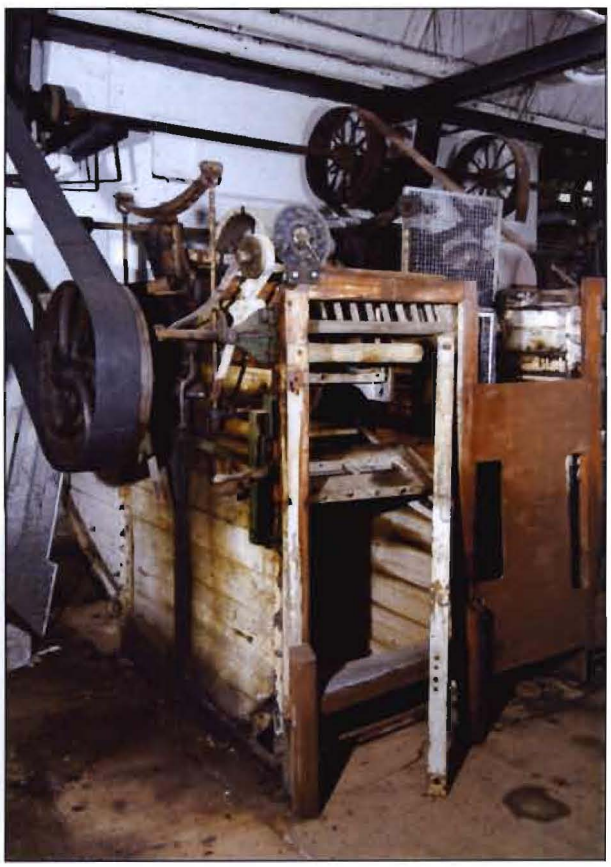
Figure 55.
Combined scouring and milling machines. [BB961016841]

Figure 56.
Scouring machines in use, 1995. [BB96/01681]

evidence of the regular maintenance and replacement of mechanical components and those parts which were in contact with the moving cloth or the hot liquor. They are of broadly similar design, each comprising a cast-iron framework supporting horizontal rollers above a wooden tank containing the liquor. A smaller internal wooden trough beneath the rollers collected the waste after it was squeezed through the cloth, keeping it separate from the liquor in the tank. The machines were belt-driven from the line shafts, and could be stopped by the use of either a fast-and-loose pulley or a friction clutch.

Figure 57.
One of the two centrifuge drying machine.s [DP043916]

A late refinement of the finishing process was to partially dry the cloth after scouring in two large centrifuges, 1.8 metres (6 feet) in diameter, located at each end of the shed. These are of early to mid-20th century date and powered by a single large DC motors situated beneath the floor (Figure 57).[81]



Most of the milling machines are of mid-20th century date, of either British or German manufacture and made entirely of cast-iron, although some older machines are of similar iron and wood construction to the scouring machines (Figure 58). Similar wooden milling machines are shown in the same locations in the 1912 photograph. The *in situ* machines all have a single pair of narrow wooden milling rollers constructed of segments arranged with the grain radiating from the axis, which enabled the rollers to be used at high pressure. Before it entered the rollers the cloth passed through a rectangular wooden box with a pivoted top panel. A lever mechanism caused

Figure 58.
A milling machine powered from the primary line shaft. [DP043884]

Figure 59.
Mechanism for agitating cloth inside a milling machine. [DP043864]

the top panel to repeatedly slap the cloth, thus agitating it to help resist the formation of 'rigs' or creases (Figure 59).

Several other items of fixed and mobile equipment were used for the efficient handling of the cloth pieces. They range in date from the early to late 20th century, but all were essential for the operation of the scouring and milling machines. The cloth was stitched into a continuous loop, after first being fed through the machine, using portable sewing machines operated by a foot treadle, several of which remain in the building (Figure 60). It was sewn into a tube for milling using a 'bagging' machine, two of which remain in the south-east corner of the shed (Figure 19, above). The folded pieces were transported around the building on low two-wheeled wooden trolleys, measuring about 6 feet by 3 feet, one of which is shown in the 1912 photograph.

Figure 60.
One of the portable sewing machines used for stitching cloth pieces. [DP043861]

After scouring, the cloth pieces formed a tightly-compressed 'rope', which needed to be unwound and flattened before stitching and milling. This was achieved using two large triangular stretching frames, which are suspended from the ceiling in the south-west corner (Figure 61). The cloth was drawn through the narrow end of the frame by rollers at the wide end, which were powered from the line shafting. The rollers had helical ridges which were angled outwards from the centre, thus flattening the cloth and stretching it to its full width. Another roller on a pivoting frame then folded the cloth onto a trolley which was parked underneath (Figure 62).

Figure 61.
A stretching frame suspended from the Finishing Shed roof. [DP043915]

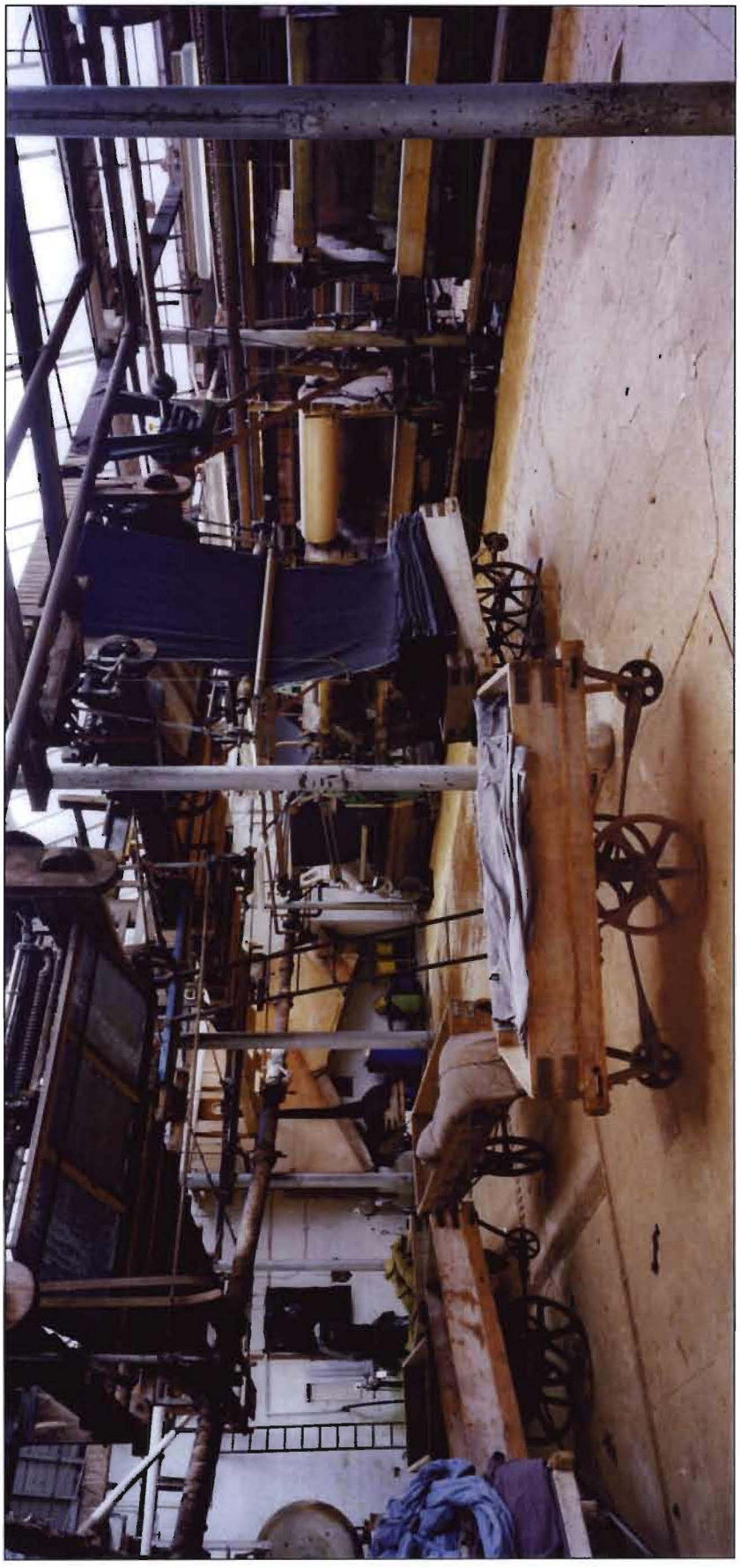


Figure 62.
A cloth piece being fed onto a trolley from a stretching frame, 1995. [BB96/01691]

The raising and cutting machinery remains *in situ* in segregated rooms, but is mostly later than the scouring and milling machines. The two raising gigs are only partly accessible in room 16a, one using a roller with teazles and the other with metal wires (Figure 63). Additional machines in room 16 were used for 'de-rigging' cloth pieces that had become creased; this was achieved by winding

Figure 63.
A teazle gig ready for use, 1995. [BB96/01677]

the cloth tightly onto steam-heated perforated rollers. Another later machine was used to stabilise or 'set' the finished cloth to prevent further shrinking. The two shearing machines are of mid-20th century date but are located in a room to the south-west of the wheel chamber that was built after the site was photographed by RCHME in 1995. They comprise a system of closely-adjusted rollers and helical cutters to accurately remove the knap, and include recent dust-extraction equipment. One is a single-bed machine, which cut one face of the cloth, and the other a double-bed, which cut both faces simultaneously (Figure 64).

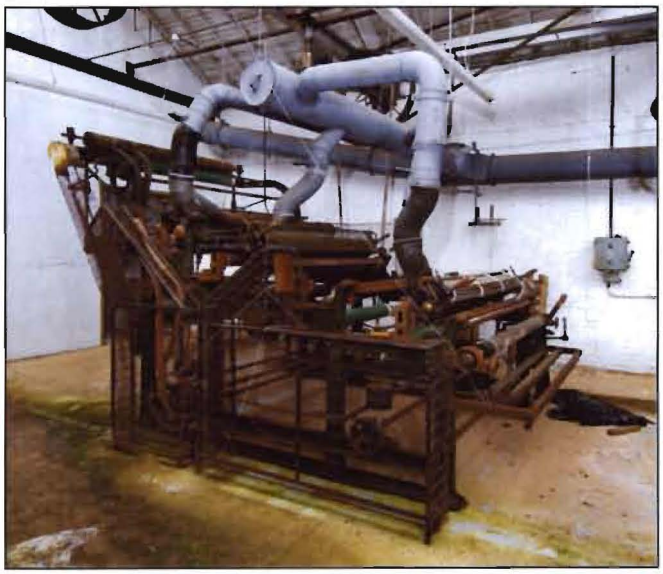


Figure 64.
A single-bed shearing machine. [DP043908]

White Goods building

The two buildings added to the south of the river were probably built for the segregated production of white and grey goods (see Historical Background). The White Goods building (Figure 24; 4 on the block plan, Figure 10) is shown on the c1886 letter head as a single-storeyed building of six or seven bays, with a small lean-to extension at the north end of its west side. The 1886-7 OS plan confirms this layout and shows the building with a central cross-wall, suggesting that it had been extended. The stone rubble side walls and north end of this building are now enclosed by the early 20th century red brick extensions, most of which are shown on the 1904 OS plan (Figure 65).

Figure 65.
The White Goods Building. The earlier phase is located at the left end of this view. [BB96/01709]

By 1904 the south end had been extended to its present length of about 12 bays and an upper storey added. The addition included a full-length ground-floor extension to the east side with a lean-to roof, and a small gabled extension on the west side, in the fourth bay from the south end. The latter has a double door, suggesting that it was used for goods access, but also has a low shaft box in its north side. A small motor, probably electric, could have been located inside the extension or outside its north wall. Internally, a line shaft hanger beneath a nearby ground-floor beam confirms that powered shafting was used along the west side of the building. A later three-bay extension was added to the middle of the west side, shown on the 1930 OS plan. The original small extension in the north-west corner was retained and partially rebuilt in the later alterations.

In the ground floor, the rubble walls of the original building are thicker and retain similar fenestration to that shown in the c1886 letter head, although the windows are now either blocked or used to enter the extensions. The stone north end retains an arched double door with red brick jambs which appears to be part of the original build. The top of the original east side wall has been lowered slightly to give clearance to a row of wide windows that were included in the raised section of the wall, just below the ceiling. The west side wall is higher and has a late 19th-century angled brick coping, suggesting it has not been lowered.

The first floor is supported by narrow joists and steel I-section beams. A narrow straight staircase is located by the west side, south of the entrance. The upper floor is open to the roof, which is supported by light, timber A-frame trusses with a single rank of purlins and a narrow ridge plank. The building is currently used for storage and light engineering and does not contain any original machinery.

Grey Goods building

Immediately to the west is an early 20th-century wide-gabled single-storeyed building of 12 bays (Figure 24; 29 on the block plan, Figure 10). This was the last manufacturing building to be added to Tone Works. Built in similar red brick to the White Goods building, it was originally used for milling grey cloths and was later converted for finishing white cloths (see Historical Background). Internally it was probably open to the roof, which is currently hidden by plastic sheeting, and does not retain any textile machinery (Figure 66).

Figure 66.
The Grey Goods Building. [DP046037]

The Power House

The interior of the Power House has not been accessible for this survey but was photographed in the mid-1990s (Figure 24, above). External evidence indicates that most of it was built to the same compact layout shown in the 1922 Building Control Plans (Figure 15, above). Constructed mostly of cement or concrete blocks, it comprises a boiler house for three Lancashire boilers, a two-storeyed economiser house attached to the west end, a full-height single-storeyed generator room attached to the north side and a tall free-standing chimney (Figure 67). The firing floor at the east end of the boiler house retains its three original arched double doors, one facing each boiler. The boiler house and generator room have similar gabled slate roofs with light metal trusses. The two-storeyed

economiser house is attached across the full width of the boiler house and projects beyond its south side. Its first floor is reached by an external stair and the ground floor by a door in the west elevation. The generator room has a separate gabled roof and is about five bays long (Figures 68 and 69). The three eastern bays of its north side are of earlier red brick with blocked segmental-headed windows, and are the remains of the 19th-century carpenter's shop marked on the Building Control Plans. The chimney is in a slightly different position to that shown in the plans. It is a tall circular stack of yellow brick and dominates this part of the site. The Building Control Plans show it adjoining the north-west corner, but it was built slightly further to the west. Its base is linked to the Power House by a flat-topped rectangular structure containing metal hatches to give access to the flue. This structure includes blocked narrow-arched openings on both sides which are distinctively-finished in a broadly-classical style; the function of the openings is not clear, but they may have contained part of the economiser or a powered fan.

Figure 67.
The Power House, with the economiser building in the foreground. [BB96/01714]

Figure 68.
The interior of the generator room, 1995.
[AA96/00753]

Figure 69.
Slate switch panel in the generator room, 1995.
[AA96/00752]

CONCLUSION

Tone Works is an unusually complex industrial site which developed over a long period and retains most of its machinery and well-preserved evidence of its power systems. It was probably the largest finishing works to be built in the South West and is now the last in the region to remain intact. This report is the first comprehensive investigation of the site and aims to give equal emphasis to the recording of buildings, machinery and landscape features. The authors have benefited greatly from the availability of a detailed archive and from information given by the managers and former employees of the firm (see Acknowledgements). The main factors in assessing the significance of Tone Works are the overall quality of preservation, the scale and date range of its buildings, the rarity of its surviving mechanical features and its association with a pioneering and highly successful firm. Comparisons with known sites in other regions suggest that its survival up to the end of the 20th century is unprecedented. Cloth finishing works of various types were built in all the main textile areas, some with a similar date range to Tone Works, but their numbers have been greatly reduced by the decline of traditional industries. A few may remain in use, particularly in areas associated with the cotton industry, but it is highly unlikely that any others retain a complete set of historic machinery or intact features of water, steam- and DC electric-power systems. The main reason for the remarkable preservation of Tone Works was undoubtedly its continuous occupation by Fox Brothers, one of the longest-surviving family firms in the English textile industry, and in particular their production of cloths that benefited from the use of traditional methods.

Buildings:

The buildings of Tone Works have seen rapid deterioration in recent years, notably that caused by water-penetration through vandalised roofs, but in 2007 the preservation of historic structures and details is still relatively good. Because the site remained in use for cloth finishing, later alterations were in-keeping with the original use of the buildings, so functional features were often retained or adapted. As a result Tone Works retains examples of all the functional building types associated with the development of woollen cloth finishing in the mid- to late-19th century; the only missing feature is a traditional fulling mill, the last fulling stocks having been removed from the site in the early 1890s. Thus the survival of the complex as a whole is significant. The buildings were all functionally related and as a group they illustrate the development of the site. Their external features offer clear evidence of the internal segregation of the varied range of processes and machinery.

Individual buildings of interest:

- The two Dry Houses are the earliest buildings. They were the largest extant structures shown on the Tithe Map. Both were later modified but retained their original functions.
- The Wheel Chamber was also modified but is probably the last surviving part of the early 19th-century mill. Its location within a later north-light shed is highly unusual.
- The Finishing Works. This was essentially a separate factory within the site. All its buildings are very-well preserved along with most of its power systems, process-water system and the original type of machinery. The Motor Room may be an early example of a building designed to accommodate electrical generating plant.
- The Power House. This was one of the last additions to the site, but is significant as one of the earliest completely intact independent power stations. Some internal machinery was removed recently.

Power Systems:

The survival of substantial parts of three successive power systems, and the mechanical features by which they were combined, is also of great interest. Before the availability of public power supplies the power system was a fundamental constraint on the design of a mill and the arrangement of its processes. The intact line shafting at Tone Works is of particular interest; all 19th-century textile mills had extensive line-shafting systems but in almost all cases these have been completely removed. Even the line shafting found in most of the preserved textile mill museums has been considerably altered, with some parts removed and others replaced. Other examples of line shafting may survive in textile mills elsewhere but are certainly extremely rare. Some historic line shafting is also known to survive in other industries, notably metal working, but these industries have experienced similar widespread losses of mechanical features. In non-textile sites the line shafting systems were normally on a much smaller scale, with more lightly-built shafts and fittings. At present Tone Works is one of only two known examples of intact line shafting to survive at a textile mill, and may be (by a small margin) the oldest and most original.

Mechanical features of the power systems that are of particular interest:

- All the components of the line-shafting system, including the brackets, bearings and the clutches used to combine the power sources.
- The remains of the water wheel, water courses, sluice mechanism and the later features of the gear chamber, by which the water-power system was adapted to drive the Finishing Works.
- The early DC electric motors, switchgear and related fittings.
- Any machinery associated with DC power generation and use.

Machinery

Tone Works still contains an intact set of machinery used for the full sequence of traditional finishing processes for woollen and worsted cloths. Most of the machines continued to be powered by the working line shafting up to the late 1990s. The Dye Works has been disused for some time but is also known to contain most of its traditional machinery and fittings. Throughout the site the machines have been repaired or replaced in the course of normal maintenance, but most are the original type in their original locations. The date of the individual machines and of their components varies considerably; more components having been replaced on the machines which remained in use longer. Detailed appraisals of the histories of the individual machines are beyond the scope of this report. As a group, however, they represent the original type of machinery and the internal organisation of processes that the site was designed to accommodate. The extensive process-water system was essential to the operation of the machinery and had a similar influence on the layout of buildings to the power system. The ponds, tanks, pumps, piping and drainage channels all remained in use and were therefore preserved as functioning components of the works.

Machinery features of particular interest:

- The traditional scouring machines in their original locations
- The traditional milling machines in their original locations
- Any surviving dye vats and related machinery (requires on-site inspection)
- The ponds and major features of the process-water system
- Smaller traditional machines which performed essential functions but may not be in their original locations, such as the raising gigs.
- Traditional machinery and equipment associated with the cloth handling and transport.

Fox Brothers and Company

The owners and occupiers of Tone Works were one of the largest and most successful firms in the South-West textile industry. Thomas Fox was in important pioneer of the factory system, having converted an Elizabethan clothier business into a factory-based firm which out-lived the 20th-century decline of the traditional textile industry. The firm he created was not a prolific innovator but was technically progressive, combining the latest thinking with established methods when it was advantageous to do so. Fox Brothers excelled most in its control of processes and its organisation of production on a large scale. The parallel integration of woollen and worsted manufacturing was a significant achievement in itself. The firm's continued ownership and management of Tone Works was undoubtedly a major factor in the eventual preservation of the site. Of additional interest are the close links between the firm and the town of Wellington. It was a major employer for generations and its influence can be seen in buildings around the town, including housing, community buildings, other industrial sites, a park and the local bank. The company's extensive archives should be recognised as an important historical resource on the origins and progress of the Somerset textile industry.

Recommendations for further research

This investigation has concentrated on the interpretation of historic buildings and the principal mechanical features. It is assumed that specialised appraisals of the engineering of the line shafting, water-power features, early electric power features and the traditional types of machinery will precede their conservation or removal.

1. Internal inspections of the Dye Works to assess the surviving dye vats and related machinery. Also to identify any early 19th-century structures and any additional evidence of the power systems (requires decontamination).
2. Internal inspection and assessment of the Power House (requires decontamination).
3. Further investigation of the inaccessible parts of the water-power system, especially the headrace tunnel and lower part of the gear chamber.

4. Further investigation of the process-water system, notably the under-floor reservoir beneath the eastern half of the Finishing Shed.

5. Research and investigation into the operation of the combined power systems, notably the clutch mechanisms.

6. Further research and on-site appraisals to ascertain the dates of individual machines.

7. Specialised appraisal of the engineering of the line shafting, including spur and bevel gearing.

8. Compile a full catalogue of the historic company archives, and hopefully secure their preservation. An up-to-date detailed study of the history of Fox Brothers and Company would make a valuable addition to the published literature on the origins of the Industrial Revolution.

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ABBREVIATIONS USED IN ENDNOTES

Some of the documents in the Fox Brothers company archive are not paginated, but are usually in chronological order. In these cases, the dates of entries are used in references.

Fox 1914	Joseph Hoyland Fox, The Woollen Manufacture at Wellington, Somerset (London, 1914)
Fox 1947	Fox Brothers and Co. Ltd, 175th Anniversary Letter from Fox Brothers & Company Limited (1947)
Fox 1958	Hubert Fox, Quaker Homespun: The Life of Thomas Fox of Wellington Serge Maker and Banker 1747 – 1821 (London, 1958)
Fox, F.H.	Fox Brothers and Co: undated typescript by F. H. Fox, *Fox Brothers & Co. Ltd.: Fifty Years' History 1883-1933*
Hagen & Fox 2000	John Hagen and Michael Fox, *More than two hundred years - Wellington and the Foxes* (Wellington, 2000)
LB 1777-79	Fox Brothers and Co.: Letter book, Nov 1777 – Feb 1779
LB 1801-02	Fox Brothers and Co.: Letter book, 1801 – 1802
LM	Fox Brothers and Co.: List of machinery, 1887 – 1953, bought for all factories, and often the date at which a machine was scrapped or sold; it includes a supplementary typescript book of machinery written off in 1949
L "U"	Fox Brothers and Co.: Ledger "U", 1798-1801
MBTW	Fox Brothers and Co.: Memorandum book of Thomas Were, 1737 onwards
MBTF	Fox Brothers and Co.: Memorandum book of Thomas Fox, 1771 – 1814 (with later additions).
MB 1876-96	Fox Brothers and Co.: Memorandum book covering the period 1876-1896, kept by an unnamed member of the Fox family
PB 1773	Fox Brothers and Co.: Pattern book, 1773
PLL	Fox Brothers and Co.: Profit and loss ledger, 1866-1904
SARS	Somerset Archive and Record Service, Taunton

ENDNOTES

1 Serge included a wide range of cloths, normally with a diagonal twill weave, that were made using combinations of worsted and wool, and sometimes other fibres including silk.

2 Fox, 1914, 2.

3 Fox, F.H., 33.

4 MB TF, 57.

5 MB TW, 137.

6 MB TW, 261.

7 Fox 1914, 97.

8 Information from Bruce Watkin concerning Sun Fire Insurance policy 459970, 1782.

9 Wellington Tithe Map, 1839, SARS D/D/RT/367; Runnington Tithe Map, 1839, SARS D/D/RT/43.

10 MB TW, 268-269.

11 MB TF, 71: details for Sun Fire Insurance policy 945701. Similar details are listed in policy 990705, 1822 (MB TF, 79).

12 MB TF, 126: Sun Fire Insurance policy 1512981, 1846.

13 A "New cut at Tone" was built in 1871, PLL, 105. A description of the new detached Boiler House states "River wall built" in 1884, MB, 1876-96.

14 Earlier weirs are mentioned in 18th-century documents but are not shown on the 1839 Tithe Maps, suggesting that they were located at the mill site.

15 In 1892 £1628:04:03 was spent on "New Filtration Buildings & Tanks" and £958:08:04 on "New Reservoir at Tone", PLL, 241.

16 LM, 38, 40.

17 Information on the use of the ponds from Michael Fox, 25-5-2007.

18 Note on disposal of waste, February 1881, MB 1876-96. An addition to the grease works was made in 1873, PLL, 107.

19 PLL, 116, 241-242.

20 The letter is dated 1892, but the engraving on the letter head shows a buildings layout very similar to that on the 25" O.S. plan surveyed in 1886-7. SARS, A\BBN/3/2 (bundle).

21 Fox, F.H., 13.

22 PLL, 101-103.

23 PLL, 120, 235.

24 PLL, 111-114.

25 MB 1876-96, entry for 3rd May 1877.

26 MB TF, 147, 152, 155, 157. In some years the stored dyestuffs were of higher value than the Dye Works buildings.

27 PLL, 102, 111-114.

28 Information on the use of this building from Michael Fox, 25-5-2007.

29 Steam Boiler Assurance Company policy 4801, MBTF, 136.

30 MBTF, 172, 178.

31 Fox, F.H., 12.

32 MB 1876-96, entry for 1885.

33 PLL, 105.

34 Chimney not on O.S. 25" plan, revised 1929, published 1930.

35 Fox, F.H., 18.

36 PLL, 242-244.

37 MB 1876-96, entries for 1893-94 & 1894-95.

38 MB 1876-96, entry for 1895-96.

39 LM, 36B.

40 Complete Specification, Heywood and Bridge's Improved Friction Clutch, Patent 6004, 25th April 1887.

41 An alternative type of clutch, which could only operate when the shafting was stopped, was used in the Motor Room – see Description and Analysis of Buildings.

42 LM, 40, 37.

43 LM, 37.

44 LM, 36B, 37.

45 Fox, F.H., 48.

46 Interview with Michael Fox, 25-5-2007.

47 Extension shown on O.S. 25" plan, revised 1903, published 1904.

48 Fox, F.H., 32.

49 Fox, F.H., 52.

50 Fox, F.H., 19, 21.

51 LM, 36.

52 SARS D\U\wel/24/1/3/641: Fox Brothers and Co. Ltd., Building Control Plan 641 of the new Power House, 1921.

53 The earlier building was extant in 1886-7. 25" OS plan, surveyed 1886-7, published 1890.

54 LM, 36.

55 ibid.

56 LM, 55.

57 LM, 36; information on water wheel from Michael Fox, 25-5-2007.

58 Information from Michael Fox, 25-5-2007.

59 The Manufacture of Woollen Goods: Messrs. Fox Brothers and Company Limited, Wellington, Somerset, *The Gentleman's Journal*, February 24, 1912, 13 – 18.

60 Ibid.

61 Interviews with Jack Hudson, 22-5-2007, and Michael Fox, 25-5-2007. The interior was inspected briefly by the author and Tim Roper, the current owner, in 2006, wearing protective clothing and equipment. This visit confirmed that most of the machinery and fittings photographed in the 1990s were still *in situ*.

62 *The Gentleman's Journal*, op cit.

63 Information given by Michael Fox, 25-5-2007.

64 The finishing technique introduced by Thomas Fox is referred to as the "mill-cut-mill" process. Information provided by Jack Hudson.

65 The term scouring is also used to describe the washing of raw wool prior to spinning.

66 Several preserved textile mills retain large-scale water power features. Coldharbour Mill, Uffculme, Devon, has a similar waterwheel to Tone Works combined with an early 20th century steam power system.

67 A comparable line shafting system dating from 1895 survives complete with its steam engine at Queen Street Mill Museum, Burnley. Other known examples are of later date, are not original or not completely intact.

68 2 inch diameter vertical holes are located in moulded protrusions on either side of the shaft journal. Information on their use for raising the shaft was given by staff at Coldharbour Mill museum, where the restored waterwheel has similar a feature.

69 For example see Fairbairn, 1863, 121-2.

70 Small buildings are shown in this area on the OS plan surveyed in 1886-7.

71 A late 19th century clock mechanism by Garth of Bristol was *in situ* in 1995.

72 Information provided by Michael Fox, 25-5-2007.

73 Sun Fire Assurance Policy 1512981 (MB TF, 126).

74 Information on the use of the Streaming Shop given by Michael Fox and Jack Hudson.

75 MB 1876-96.

76 A 1912 description (not corroborated) states that the shed covered an area of 21,000 square feet and contained 32 fulling machines and 26 scouring machines which used 60,000 gallons of treated water per hour. *The Gentleman's Journal*, Feb. 24th, 1912, 16.

77 The other example is Queen Street Mill Museum, Burnley, built 1894-5 and partly rebuilt in 1918. It was preserved after a protracted campaign in the 1980s as a working museum with a steam engine, boiler, line shafting and power looms. As a cotton weaving mill it represents a contrasting aspect of the textile industry to Tone Works.

78 F.H. Fox, 19, 21; LM, 36.

79 Information from Michael Fox, 25-5-2007.

80 Ibid.

81 One of the 72" Cylinder Drying Machines was purchased from Riley in 1914, LM, 40.

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Figure 9	Tone Works in c1886, taken from the heading of a letter dated 1892 [SARS A\ BBN/2/2].	Used with permission of SARS.
Figure 10	Undated Block Plan of Tone Works, showing the site in the mid-20th century [Fox company archive].	Fox Brothers and Co.
Figure 11	A depiction of Tone Works from the north-west in c1920 [Fox company archive; AA95/06574].	Fox Brothers and Co.
Figure 12	Interior of the Finishing Shed in 1912, taken from the east end, facing west [Fox company archive, AA95/06574; also published in The Gentleman's' Journal, 1912].	Fox Brothers and Co.
Figure 13	Patent drawing of the Heywood Friction Clutch, 1887 [Patent 6004, 25th April 1887, British Library].	Copyright British Library
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