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Lowwood Gunpowder Works and Ironworks and the workers' hamlet of Low Wood, Cumbria: an archaeological and architectural survey

Marcus Jecock, Christopher Dunn, Philip Sinton, Tony Berry, Nigel Fradgley, Ian Goodall and Simon Taylor

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Surveyed by:	Marcus Jecock, Christopher Dunn, Philip Sinton, Tony Berry, Nigel Fradgley, Ian Goodall and Simon Taylor
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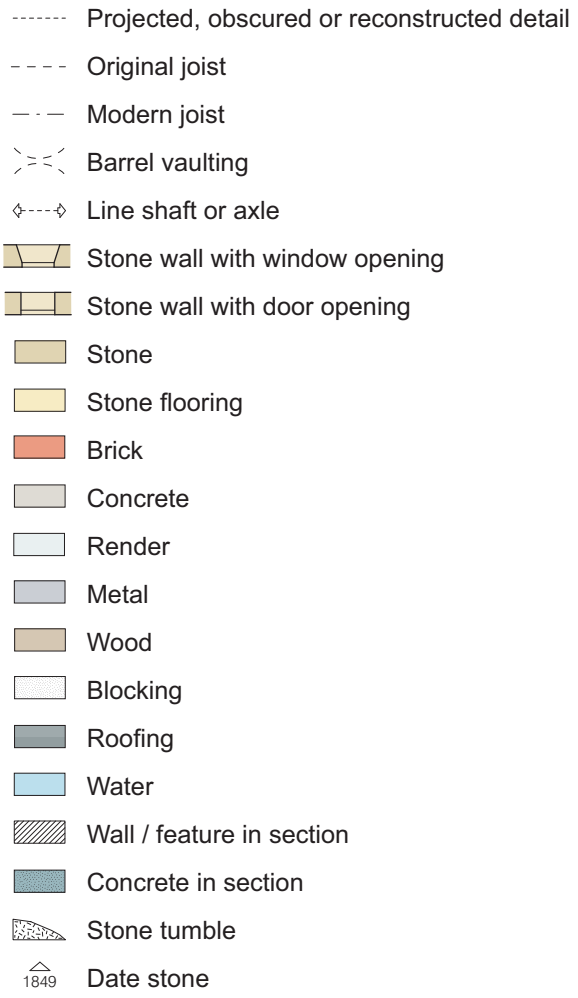


1. INTRODUCTION, SITE LOCATION AND SUMMARY

In winter and spring 2004, English Heritage (EH) carried out archaeological and architectural survey and investigation at the site of the former Lowwood Gunpowder Works in Cumbria. (Although the place name is written as two words, Low Wood, both the gunpowder factory and the blast furnace which preceded it are normally referred to in modern literature as Lowwood). The survey formed part of a wider thematic project investigating gunpowder manufactories across Cumbria, initiated in June 1999 (Dunn 2001; Jecock 2003) as the logical progression to EH's Monuments Protection Programme's (MPP) Step Reports for the gunpowder industry nationally (Gould 1993; Chitty 1996). Although there has been considerable interest and research into the Cumbrian works in recent years, directed at both the group as a whole and individual sites (*eg* Wilson 1964; Marshall & Davies-Shiel 1969, 75-88; Crocker 1988a, 36-41; Crocker and Crocker 1992; Patterson 1995; Palmer 1998; Tyler 2002), this has mostly concentrated on the documentary evidence with little formal examination or detailed recording of the physical remains. EH's Cumbrian Gunpowder Industry Project is intended to rectify this omission, and will aid conservation management of those works which have been designated in whole or in part as protected monuments; the inclusion of all sites irrespective of their current level of designation will also enhance our overall understanding of what was an important regional industry.

The Lowwood works is one of seven powder manufactories (eight if Gatebeck is treated as two sites) which operated in the historic counties of Westmorland and the Furness area of Lancashire (since 1974 both amalgamated into modern day Cumbria) at various times between *c* 1764 and 1936. The seven factories were initially owned by five companies, all producing gunpowder chiefly for the civilian, as opposed to military, market. Geographically, the factories were concentrated in four areas: Old Sedgwick, New Sedgwick, and Basingill lie in close proximity along the banks of the River Kent 5-6km south of Kendal; the Gatebeck High and Low Works lie adjacent to each other about 4km to the south-east of this first group; Blackbeck and Lowwood occupy neighbouring valleys close to Haverthwaite; whilst Elterwater forms an outlier at the foot of Great Langdale (Fig 1).

The industry became established in Cumbria mainly in response to the increasing national demand for blasting powder from mines and quarries through the 18th century. The Lake District provided a very suitable environment for gunpowder manufacture: the numerous rivers could supply the waterpower needed by the different processes, while the rural and wooded locations were sufficiently remote from populous areas to minimise the effects of any explosions. Later on, as more regard began to be paid to the safety of the workforce as well, several mills even incorporated trees, natural rock outcrops and low hills into their layouts as barriers to dampen and help contain blasts. Furthermore, timber was available locally both for charcoal manufacture and the making of barrels and packing crates, whilst proximity to the coast meant that other raw materials (sulphur and saltpetre) could be readily imported. As a result of these overseas contacts – mostly routed through Liverpool – the Cumbrian gunpowder industry was able to build up a healthy market for its products

abroad, particularly in parts of the British Empire, as well as at home. After *c* 1860, alternative forms of explosive based on the nitration of a variety of organic compounds began to appear. Many English powder works diversified into producing the new explosives, but the Cumbrian mills stuck with their traditional stock-in-trade, now re-christened blackpowder to distinguish it from the newer forms. Despite this failure to diversify, the Cumbrian blackpowder industry continued to prosper until the end of World War I, when overcapacity in explosives manufacture resulting from the gearing-up of production to meet wartime demand led to the Cumbrian mill owners merging with many of their British competitors to form Explosives Trades Ltd and begin a process of rationalisation of the industry. In 1920 Explosives Trades Ltd became Nobel Industries Ltd, in 1926 itself incorporated into Imperial Chemical Industries Ltd (ICI). In 1928 ICI extended the programme of site closures to Cumbria, with blackpowder production finally ceasing there in 1936 when Gatebeck was shut down. After this date all British blackpowder manufacture took place at a single factory - Ardeer in Scotland (Cocroft and Tuck 2005, 231; Crocker 1988a, 1-2; Patterson 1995, *xi* and 44).

The Lowwood gunpowder works was built around the site of an 18th-century blast furnace/ forge complex, itself allegedly on the site of an earlier bloomery forge. The factory eventually lined both banks of the River Leven adjacent to the hamlet of Low Wood, 0.5km south-east of Haverthwaite. At its greatest extent it covered *c* 8.8ha (21.75 acres) centred on National Grid Reference (NGR) SD 349 839 (Fig 1), but the company possessed in addition three local off-site store magazines - one at Busky about 0.5km west of the main factory, and two more in Roudsea Wood on the shore of the Leven estuary (Fig 2) - owned or leased other land in the area, and were also responsible for erecting many of the buildings which constitute the present Low Wood hamlet.

The Lowwood works is the sixth of the Cumbrian blackpowder sites to appear in this EH report series, after Old Sedgwick (Jecock and Dunn 2002), Basingill (Hunt and Goodall 2002), Elterwater (Jecock *et al* 2003), New Sedgwick (Dunn *et al* 2003) and Blackbeck (Dunn *et al* 2005). Archaeological survey was carried out across the whole factory site to level 3 standard (as defined in RCHME 1999, 3-5), but a more flexible approach was adopted for buildings survey with only selected buildings recorded at architectural level 3 (RCHME 1996) as deemed appropriate. Structures surviving from the preceding blast-furnace phase, plus the Busky magazine and buildings comprising Low Wood hamlet, were included in the survey at architectural level 1 only; the Roudsea magazines had previously been recorded by RCHME/EH at level 2 as part of a project into the iron industry and related woodland industries of Furness and southern Lakeland (Bowden 2000, 32-5; NMR records). Fieldwork was backed up by documentary research, comprising a reading of published sources and a search for historical archive material. A set of high-quality colour archive photographs was also taken by EH photographers as part of the recording process: many are reproduced in the present report. Further digital 'snapshot' photography was undertaken on site during the investigation process, some of which is also reproduced in the current report.

The company was established in 1798 by four local entrepreneurs - Daye Barker, Capt Joseph Fayrer, James King and Christopher Wilson, Jnr - and was the second gunpowder

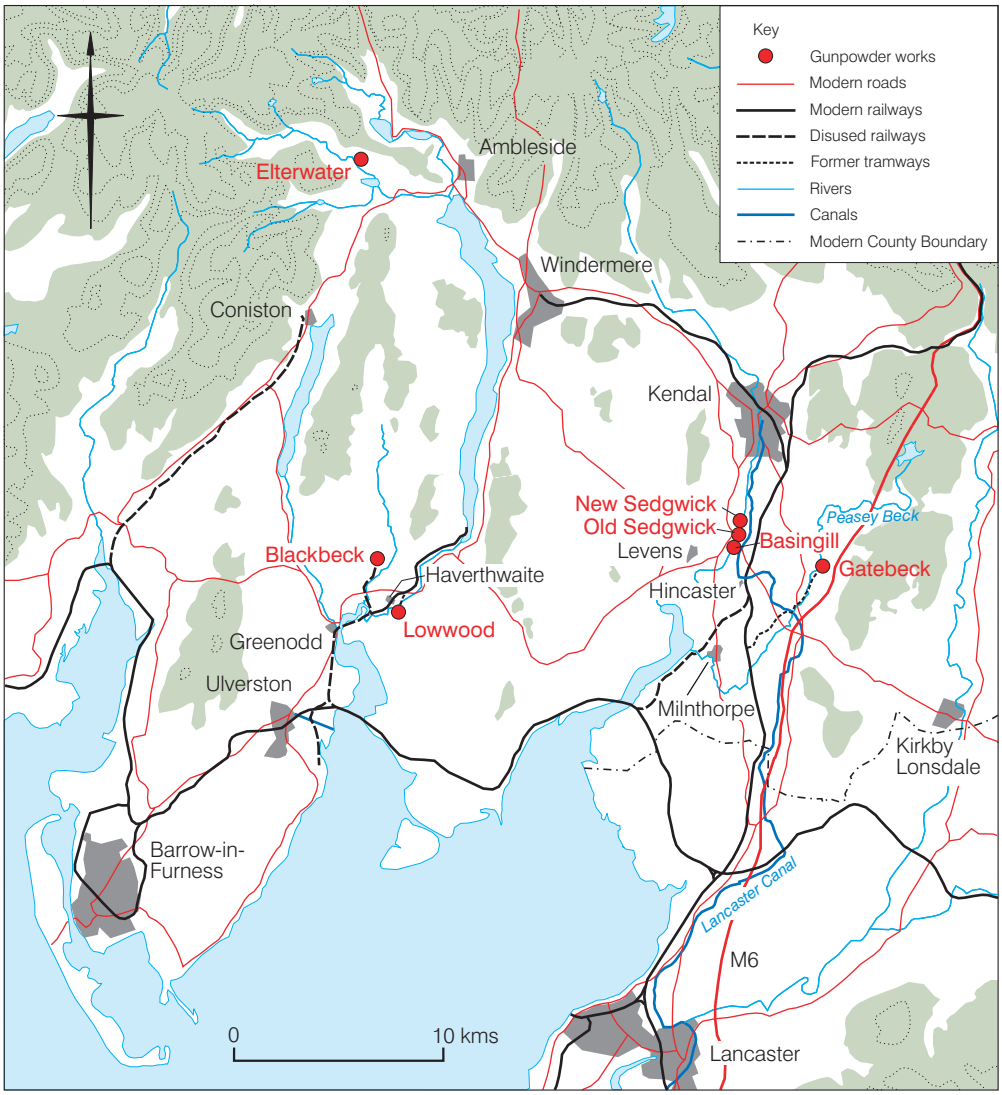


Fig 1. General location diagram

works to open in Cumbria after Old Sedgwick and its Basingill outstation (established *c* 1764/1790). The four partners established their works around the remains of a disused blast furnace on the left bank of the Leven, itself supposedly constructed over the remains of a bloomery forge operational between *c* 1603 and 1622. However, there is some uncertainty over the precise location of this 17th-century forge, which contemporary documents refer to as Burnbarrow, not Lowwood. The gunpowder company took the lease of the blast furnace site together with its existing weirs and leats, but seem to have had to construct a replacement weir higher upstream feeding an extended headrace and leat system in order to provide an enlarged head of water to power all the various process buildings required for the new factory. Despite the heavy initial investment, the company was soon prospering. It had, for example, paid off its external loans by 1806, and although it commenced powder production in the late summer of 1799 running only one, or at most two, incorporating mills, the number of mills had risen to fourteen by 1846.

The company traded under a number of different names: in the early years Fayrer, King & Co, Fayrer, Barker & Co, and the Low Wood Gunpowder Co are all recorded and seem to have been interchangeable depending on with whom the company was doing business. But by *c* 1815 only the latter name or Daye Barker & Co appears on company correspondence.

In 1863 following a serious accident, the firm was restructured into the Lowwood Gunpowder Company Ltd, and for ease of reference and in line with most modern usage, it is as the Lowwood Gunpowder Company or works, or simply as the company, that the gunpowder factory will be referred to in the present report regardless of period. The new company did not prosper, however, and in 1882 it was sold to W H Wakefield & Co, owners of the Gatebeck factory and Basingill outstation (Old Sedgwick had closed by this time and been replaced by a new factory at Gatebeck). Despite the change in ownership, the factory continued to trade under its old name. In 1883/4 the works was connected by horse-drawn tram to the Furness Railway Company's station at Haverthwaite on the other side of the River Leven, the extra land crossed by the tram line subsequently being used for new buildings associated with the production of blasting cartridges. In 1918, Wakefield's, along with the other three remaining Cumbrian blackpowder manufacturers, all merged into the new conglomerate, Explosives Trades Ltd, which by 1926 was part of ICI. Despite purchasing the freehold of the site in 1927 and modernising much of the infrastructure, ICI closed the works in 1935 due to a general downturn in demand for blackpowder. At closure all the so-called 'danger' buildings within the 'licensed' area where powder had been processed or stored were set alight as required by law to prevent subsequent accidental ignition of powder residues which might remain, but non-danger buildings were simply abandoned. Some of the more modern machinery was shipped off to ICI's Ardeer factory for reuse; undoubtedly other equipment was sold for scrap or, if it was too big or awkward to be removed, simply left on site.

During World War II, the disused works became an army base or camp for Italian prisoners of war, and several 16-foot-span Nissen and other huts were erected. In 1952/3 a hydro-electricity station was constructed close to the end of the tailrace in order to generate power for the National Grid, and the consequent re-routing of part of the headrace led to the demolition and/or burial of several former gunpowder structures. Further buildings were demolished *c* 1965 when the weir was heightened in order to help shore up the sides of the heightened headrace, and around the same time a strip of land south of Haverthwaite station, formerly part of the works, was compulsorily purchased by the Ministry of Transport for the route of the A590 trunk road (Backbarrow by-pass).

Otherwise, the site is largely as abandoned in 1935, although heavily overgrown. It is now used as a park for eight static caravans, with small areas north and south of the river let out as yards to local builders. The buildings forming the 'Clocktower complex' at the south-west end of the site (the former saltpetre refinery) are currently let out as small industrial or retail units, whilst other factory buildings in the same area have been converted to domestic use, and, together with the workers' cottages in Low Wood hamlet, are rented out to tenants. In consequence, in 1996 Lowwood was identified by EH's MPP Step 4 report (Chitty 1996) as the 'best northern example surviving' of a gunpowder factory with an 'exceptional range of components and intact layout with good surviving building groups'. This resulted in 1999 in most of the area on the south bank of the Leven (very much coterminous with the post-1875 'licensed' area of the works) being designated a Scheduled Monument (RSM No. 27805). The extant buildings in the hamlet and at the south-west end of the site were excluded from

the scheduled area at this time, but the Clocktower complex had already been designated a Grade II listed building (Department of the Environment 1987, 35).

The present EH investigation has shown that the current overall level of preservation across the site is good, although the survival of individual gunpowder features tends to be either good or very poor – in the main due to the policy of selective demolition when the works closed, exacerbated by alterations made to parts of the site in the 1940s, 1950s and 1960s in connection with wartime use as an army base/ PoW camp and subsequently for electricity generation. The principal surviving gunpowder features are buildings at the south-west end of the site, in particular the saltpetre refinery - which retains many original structural features and would seem to be the best-preserved example of its type presently known nationally - the weir, the headrace (although now heightened, partly re-routed, and in many places re-faced in concrete), a number of waterwheel and turbine pits (in the case of the sawmill with the original turbine installed in 1910 still *in situ*), various blast banks and walls, and features relating to the former works tramway. Within the scheduled area, only two gunpowder buildings (both boiler houses serving stove houses) are still roofed, but both retain original fittings (in one case a Robey boiler). All other buildings in this area were fired in 1935, but many constructed at least partly in stone such as the incorporating mills, corning and glazing houses and stove complexes, have walls upstanding in places to gable height, and preserve details of the internal layout of machinery and drive mechanisms; a range of other buildings, including the sawmill, an expense magazine, dust house and press house, are preserved only as wall footings and/or concrete floors. Several earthen blast banks also survive. Much of the former course of the tramway system, laid out in order to facilitate movement of materials around the site, can still be traced on the ground in earthwork form. A number of wagons and vans used on the tramway remained on site following closure in 1935; two box vans have since been restored and are now kept by the Lakeside & Haverthwaite Railway in their yard at Haverthwaite Station. All three local off-site store magazines survive to various degrees: one in a ruinous condition, the other two converted into domestic residences. Some of the charcoal retorts used at Lowwood also survive, now relocated to the entrance to the Ulverston Canal (Fig 1) where they have been sunk into the ground for use as mooring bollards.

EH has also demonstrated that a range of other features survive which date to both before and after the gunpowder works. Whereas previously it was believed that the only extant remains of the 18th-century blast furnace were the ore store and charcoal barn, preserved by virtue of their reuse as part of the gunpowder works, the present investigation has shown that elements of a probable stable, a second charcoal barn, plus the bridge house and casting sheds to the blast furnace itself were also reused and survive at least in part. It is probable that a ruined weir which the survey has identified is earlier still, perhaps part of the 17th-century Burnbarrow bloomery forge. Later survivals include the concrete hut-bases of the World War II army base/PoW camp, and even a turbine and dynamo installed post-war in the basement of one of the disused gunpowder incorporating mills to provide electricity for houses in Low Wood hamlet.

Since EH completed fieldwork, there has been talk of the viability of turning all or part of the site into a visitor attraction (*Westmorland Gazette*, 6 Aug 2004; information from Ron Mein).

It is hoped that the present investigation and report will inform and feed into this process. However, it must be emphasised that the site is private property, with no automatic right of public access. In addition, it is potentially a dangerous environment with hazards of unfenced deep water and wheel-pits, crumbling masonry, and falling trees. Unauthorised visits are therefore not only ill-advised, but also a matter of trespass.

2. GEOLOGY, TOPOGRAPHY AND LAND USE

The Lowwood gunpowder works lies on land which until the early 20th century formed part of the Bigland estate, centred on Bigland Hall adjacent to Bigland Tarn on the left bank of the River Leven. The Leven is a relatively short river, draining the southern end of Windermere into Morecambe Bay (Figs 1 and 2). However, its valley is an ideal location for industrial processes requiring water power, for Windermere and its tributary streams and tarns mean that, in reality, the river drains a catchment area of 285 square km, with flows in part regulated by the balancing effect of the mere. In addition, the river falls some 30m over a distance of 4km between Newby Bridge at the southern end of the lake, and sea level at Low Wood (the Leven is tidal until *c* 0.5km below Low Wood bridge at ordinary tides). For much of this length the river occupies the steep-sided Backbarrow gorge – in origin a glacial meltwater channel (Trueman 1971, 251-2) - cut down through Silurian siltstones and intercalated sandstones of the Bannisdale Formation (British Geological Survey 1997), with only limited flat ground on either bank. However, at Low Wood the gorge starts to broaden as it runs out on to the narrow Cumbrian coastal plain fringing the northern edge of Morecambe Bay, and the gunpowder works occupies a long, narrow terrace on the river's left bank. The

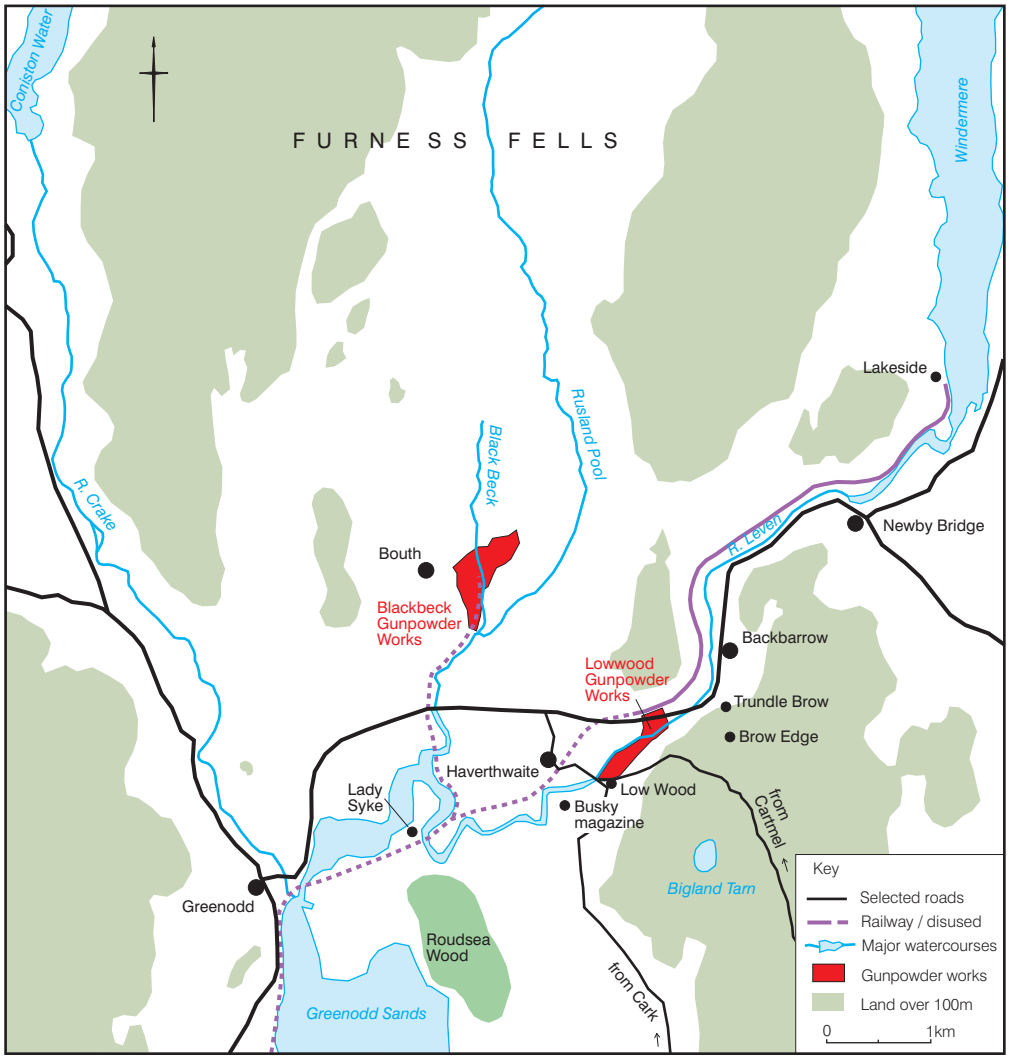


Fig 2. Local location diagram

fall on the river between the top and bottom of the terrace is 6.7m, offering the potential to generate about 300kW of power (Wilson 1964, 58).

The terrace appears to be formed mostly of coarse gravels, but incorporates a number of rock outcrops. One such outcrop opposite the upstream or top end of the terrace actually constitutes the island of Bleaberry Holme in the middle of the river (*eg* Figs 7 and 8), while lower down a number of smaller, gravel islands and shingle banks have formed where the river loses force as it meets tidal waters. These latter islands and banks are constantly being remoulded, but the largest and most permanent is known as Ford Island, and is where the old road between Cartmel and Haverthwaite bridged the river until the early 19th century. A number of small streams must formerly have run across the terrace, but are now intercepted by the gunpowder-works headrace and there is no evidence for their erstwhile courses within the area of the factory.

An early estate map of 1796-9 (Fig 3 and section 4.1 below) shows most of the terrace already parcelled up into a series of fields, with only the very northern end and a thin strip of land bordering the river wooded. Subsequent maps and plans (Figs 4-8) suggest that this pattern of vegetation was perpetuated throughout the life of the gunpowder works, with the land bordering the river afforested but only a thin scattering of trees across the main central and southern parts of the factory area.

During World War II, the site became an army base or camp for Italian prisoners of war. Part of the former factory south of the Clocktower complex became allotments at this time, but immediate post-war aerial photography suggests little visible change in land use elsewhere. Since the war, the standing buildings at the southern end of the site have been let out for light industrial or residential use, but apart from the installation of a hydro-electricity station in 1952/3 which reused the old gunpowder headrace, the area of ruined danger buildings north-east of the Clocktower complex has seen little use or active management, and is now largely covered by self-sown trees and scrub vegetation. Some tree-felling and clearance of undergrowth was undertaken here in 2003-4 in selected areas to aid the current survey and to help curtail root damage to standing structures from ivy and weed trees; however, without continued, regular, management, these areas will quickly revert to their former overgrown state. This part of the site is now home to two builder's yards and eight static caravans – the latter mostly parked on the concrete bases of wartime huts – but otherwise is little visited except for purposes of water management, principally the control of sluice gates in connection with power generation.

3. PREVIOUS RESEARCH

Much of the published research into the Cumbrian iron industry has focussed on the documentary material. The standard text by Alfred Fell (1908) appeared almost a century ago, and more recent studies have tended to concentrate on individual sites or historical personages: the main ones relevant to Burnbarrow forge and Lowwood blast furnace are by Colin Phillips and Brian Awty (*eg* Awty 1977; Phillips 1977a and 1977b; Awty and Phillips 1980). The former Royal Commission on the Historical Monuments of England (RCHME) undertook a study of the surviving field evidence for the iron industry in the 1990s, subsequently published by EH (Bowden 2000), but although this examined the physical remains at a sample of sites, Lowwood was not one of those surveyed or recorded in detail.

The earliest historical account of the Lowwood gunpowder works is to be found within a short piece written for the ICI in-house magazine towards the end of 1929 whilst the factory was still operational (Imperial Chemical Industries 1929). The article is brief, but nonetheless informative, outlining principal milestones in the histories of all five of the Cumbrian blackpowder manufacturers which ultimately came together to form ICI's North of England Gunpowder Group. It was published as part of a series of potted histories of the Group's constituent companies, and has been used uncritically by most subsequent researchers. A more general history of ICI and its founding companies published a few years afterwards (Imperial Chemical Industries 1938) contains no new information and does no more than précis the article.

Academic research into Lowwood gunpowder works commenced in 1964 with Paul Wilson's seminal overview of the Cumbrian blackpowder industry (Wilson 1964). Whilst this contains just two pages devoted to Lowwood, and is totally reliant on the 1929 article for the later history of the works, it does include original commentary on the company's early history gleaned from papers then recently deposited at the Lancashire Records Office. Four years later in 1968, aspects of these same papers were analysed in greater detail by Alice Palmer for an undergraduate dissertation in the University of Lancaster School of Education; this dissertation has since been published (Palmer 1998). Around the same time, Mike Davies-Shiel was also beginning to research and record the history of the various Cumbrian blackpowder sites, and, encouraged by Wilson, visited Lowwood for the first time in 1965. Over the succeeding years he re-visited the site on several occasions, taking slides and recording the sites and functions of buildings through fieldwork and historical research, the latter aided by the memories of the late George Shackley who had served a six-year apprenticeship at Lowwood from 1922. Davies-Shiel subsequently incorporated some of this material into a review of the Cumbrian gunpowder industry as part of a book on the industrial archaeology of the Lake District (Marshall & Davies-Shiel 1969, 75-88), but much more remains unpublished. Ron Mein, a local historian born in Haverthwaite, also communicated with George Shackley before the latter died, and has used the information obtained to re-create the layout of certain buildings within the factory; again, all these data are unpublished.

Published research of the last twenty years has dealt almost exclusively with the documentary record. Some does no more than summarise and make available to different interest groups information which already exists in print elsewhere, as for example the two-paragraph entry for Lowwood in the Gunpowder Mills Gazetteer (Crocker 1988a, 39-40), and a small privately-printed booklet produced for local sale (Crocker 1988b). A spin-off from the latter publication, however, was a short article detailing research on the likely origins of the Lowwood works clock housed within the eponymously named Clocktower complex (Crocker and Crocker 1989). Otherwise, two detailed histories of the Cumbrian gunpowder industry have appeared in the last decade. The first was written by Ted Patterson, a former ICI employee based at Ardeer in Scotland - whither blackpowder production transferred after the closure of the Cumbrian factories - who had access to records not seen by previous commentators, principally an annotated site plan which accompanied the Explosives Inspectorate's issuing of amending licence no. 3034 in 1926, and a copy of the final site Manufacturing Method Book dating to 1933/4 (Patterson 1995, 15-19 and plan facing page 15). However, the published text and plan contain errors and misunderstandings, and the nature of the source material means that discussion is limited very much to production techniques in the final years of the factory's life. More recently, Ian Tyler's chapter on Lowwood (Tyler 2002, 97-154) makes use of all the readily available published material plus hitherto unpublished information taken from a reading of surviving company papers archived at Preston and Ulverston (section 4.2 below). Unfortunately, certain of Tyler's statements appear at odds with other information seen by EH, and for the time being must be treated with caution: as the book contains no references in the text, it has not been possible to reconcile all such discrepancies by checking against original sources.

4. HISTORY AND DOCUMENTARY SOURCES

The main purpose of this chapter is to review in some detail the history of, and documentary sources for, the Lowwood gunpowder works.

The principal documentary sources are two deposits of surviving company papers. One collection resides at the Lancashire Records Office (LRO), the other at the Ulverston Heritage Centre. The former collection is made up of miscellaneous letters, accounts and receipts, *etc*, in the main covering the company's early years from 1798 to 1832, plus a much smaller body of material for the period up to 1846; the latter comprises a number of letter books for the years 1850 to 1920 recovered from a safe at the works in the mid-1980s and donated to the former Ulverston Civic Society, now known as Heritage First! (HF). Neither collection comprises a complete record of the company's activities for the period in question.

Full primary research into such a large body of material is obviously beyond the scope of the present report, and EH has read only a selected sample of what is publicly available. Many documents at the LRO are in a poor condition and considered too fragile to be produced for inspection anyway, although greater use has been made of the HF collection which, since it has been transcribed onto computer, is accessible remotely and electronically searchable by keyword. EH has also been able to approach both collections through the filter of secondary sources. Alice Palmer analysed papers at the LRO covering the period *c* 1798-1810 for an undergraduate dissertation in 1970, since published (Palmer 1998), while Ian Tyler seems to have read at least a selection of the available documentation for the Lowwood chapter in his recent book (Tyler 2002, 97-154). However, neither author references their material in detail, making it difficult now to identify specific source documents used. In addition, Tyler's work seems occasionally to confuse and conflate events.

Other sources of primary information consulted for the present report were: the title deeds to the site now held by the Trustees of the A While Estate; a small collection of company correspondence belonging to Brian Patrick of Low Wood; plans, both published Ordnance Survey mapping and unpublished factory plans in private possession; a copy of ICI's final site Manufacturing Method Book (MMB) written in 1933/4 and other material - particularly a number of photographs of the works taken in 1928/9 - deposited in the Edward Patterson Collection at the National Monuments Record Centre (NMRC) in Swindon; local newspaper reports of serious accidents, supplemented after 1875 by special reports issued by HM Explosives Inspectorate; and last but by no means least, the collected knowledge and photographs of Mike Davies-Shiel and Ron Mein. Miscellaneous other documents which bear on the history of the works also exist at the LRO, the Barrow and Kendal branches of the Cumbria Records Office (CRO(B)) and CRO(K)), and at the Hampshire Records Office (HRO): the most important of these are undoubtedly Bigland family papers. Detailed references to all sources used by EH, both primary and secondary, are listed in chapter 10.

However, as the gunpowder works took over the site of a blast furnace, itself supposedly built over a bloomsmithy or bloomery forge, the chapter will begin with an overview of the

history and documentary evidence for the earlier use of the site by the iron industry. This is drawn mainly from published secondary sources.

4.1 The Iron Industry: Burnbarrow Bloomery Forge and Lowwood Ironworks

According to Alfred Fell (1908, 200), industrial activity at Lowwood began with the erection of a bloomery forge sometime between 1603 and 1609. Fell's evidence for equating this forge with Lowwood is uncertain. All published documentation refers to the site as Burnbarrow, not Lowwood, and by the mid-19th century the former place name is only recorded in connection with a wood and moss situated some way south and west of Low Wood hamlet (Ordnance Survey 1851). Indeed more recent commentators (*eg* Awty and Phillips 1980, 26 fig 1, and 35) locate the forge no more precisely than to Cartmel parish generally. A close reading of the published evidence, however, suggests that Fell may well be correct. The documents reveal that the forge was water-powered - and must therefore have been sited adjacent to a suitable stream or river - and also stood on land belonging to the Bigland family. Lowwood fulfils both criteria. In addition, Bigland family papers deposited at the CRO(K) contain a bundle of documents labelled 'Burnbarrow and Lowwood' suggesting the two names are interchangeable. However, pressure of time has meant that EH has been unable to examine these papers in detail for the present report.

In 1609 the forge belonged to John Gardner and Thomas Robinson who transferred their interest in it to one William Kellett, (Fell 1908, 200). On 30 December 1614, William Wright, a local man and later described in the Cartmel parish registers as 'hamerman' or 'forgeman of Burne Barrowe', took out a five-year lease on the property (Brierley 1907, 54 and 163; Phillips 1977a, 36-7; Awty and Phillips 1980, 35). Wright operated the forge for several years, but seems to have been in dispute with George Preston of Holker over water rights for much of the time; Preston even destroyed the dam and otherwise interfered with the works on at least three occasions, finally forcing Wright to abandon Burnbarrow around 1620-2 and concentrate his activities at other forges he part-owned at Force Forge and Cunsey (Phillips 1977b, 20-1; Awty and Phillips 1980, 35). Various lawsuits ensued, including an investigation by the Crown as to whether Burnbarrow lay on Duchy of Lancaster land in contravention of a decree not repealed until 1616 (Awty 1977, 97). Despite the fact that depositions taken in evidence clearly state that the forge lay on land held by the Bigland family as customary tenants of the Crown (Fell 1908, 201; CRO(B) BDKF/241/9), Wright was still able to sell what remained of it in 1661 to John Bigland. However, the forge does not seem to have been worked at any time after 1622, and in 1723 the slag heaps were sold to the Backbarrow Company to be re-processed in the new blast furnace there (Fell 1908, 201).

Notwithstanding the forge's demise, the Bigland family seem to have been keen to exploit the potential of the Burnbarrow/Lowwood site with its access to water power, for industrial use, and in 1728 John Bigland's eldest son, also called John, agreed to lease land at Low Wood to Richard Ford of Cunsey to construct a blast furnace. The agreement came to nothing, and Ford later contracted to build a blast furnace at Nibthwaite. In 1747, however, George Bigland (younger brother of this second John) who had succeeded to the family estate, successfully leased the site for a term of 51 years to Job Rawlinson, William

Crossfield, George Drinkall and Isaac Wilkinson, partners in the Lowwood Company, with rights:

> to erect and build any Furnace or Furnaces for Smelting of Iron Oar and Casting of Iron Metall or any Forge or Forges for refining Iron and beating the same into Barrs or any Bark Houses Coal Houses or other Buildings which may be necessary for making refining boreing grinding or polishing of Iron…and likewise all the right title … in and to the River or Water commonly called Leven River or Backbarrow Water which adjoins the said messuage … with full liberty … to make such Cutts Sluices Foundations Channels Watercourses to and from the said River … to the said intended Ironworks.

A charcoal-fired furnace with a dam and leats to power the bellows plus a number of 'coal houses' (that is, charcoal barns) and workers' cottages were duly built, and grindstones procured, but the polishing side of the business did not prosper and was soon replaced by a forge (Fell 1908, 218-20). On the basis of the documents quoted by Fell and parallels with other sites, Bowden (2000, 64) has recently suggested that the forge may have been powered by a weir and headrace separate from that powering the blast furnace, but evidence compiled for the present report does not support this idea (this section below and section 4.2). It was probably also at this time that a quay called Bigland Dock was constructed about 200m downstream of the blast furnace on the same bank of the Leven, through which raw materials could be imported and the finished product shipped out; this quay stood at the approximate upper limit of normal tides (Bowden 2000, 36-7).

George Bigland died in 1752, and was succeeded by his son, George the Younger, then only two years old. By 1760 only William Crossfield of the original partners was still connected with the company, the other three having been replaced by John Sunderland, Thomas Sunderland (who had married George Bigland's widow) and John Wilson; by 1769 even Crossfield had been replaced by Thomas Sunderland's son, also called Thomas. In the same year the company agreed to pay £15 in damages to John Sawrey who owned a parcel of woodland known as Stangend [*sic*] in Colton parish on the opposite bank of the river, and against whose land the company's weir abutted, in order to secure the rights to maintain the weir at that location. In 1782 the company sold the business to the rival Backbarrow concern (by then merged with the Newland Company), who in 1785 paid John Sawrey an additional £7 7s 0d in damages to cover the period since they had taken over the lease and to safeguard future rights to the weir. The real motives of the new owners in acquiring the Lowwood lease, however, appear to have been in order to remove competition to their own blast furnaces at Newland and Backbarrow, for they closed Lowwood in 1785 having operated the complex for no more than four years (Fell 1908, 218-20; CRO(B) BDKF/241/8).

Recent commentators (*eg* Bowden 2000, 8 and 68) have followed Fell (1908, 220) in assuming that the Lowwood blast furnace and forge were both dismantled at closure in 1785, but Bigland family papers deposited at Kendal (CRO(K) WD BGLD 2420) make clear that all buildings erected by the original lessees were still standing when the lease expired in 1798,

albeit in a somewhat dilapidated condition; the weir(s) and races were also broken down and silted up. George Bigland sought counsel's opinion on whether he could force the Backbarrow Company to carry out repairs. The exact legal advice is not recorded, but both parties agreed to a release in February 1799 containing covenants stipulating that the Backbarrow partners would pay Bigland £25 damages annually for fifteen years provided that no furnace or forge was allowed to operate on the site during that period.

It seems likely that an estate map in the Kendal Record Office (CRO(K) WPR/89 PR/2716/9), which has hitherto escaped the notice of researchers, actually records the layout of the disused ironworks at this time. The map (the relevant portion of which is reproduced here as Fig 3) is one of a series of divorced surveys of separate land holdings in the Upper Holker division or township of Cartmel parish which survive at Kendal (CRO(K) WPR/89 PR/2716); it portrays land held by the Bigland family, and therefore includes the site of Lowwood.

The context for this series of surveys is uncertain – all are anonymous and undated. However, they are very similar to, and therefore may well be the source for, the early 19th-century divisional enclosure map bound in with the final Cartmel Enclosure Award (CRO(K) WPR/89 Z3); if so, they could have been made anytime between 1796 - the year the original Enclosure Act for Cartmel parish was passed (Whyte 2003, 39) - and 1809 when the final apportionment was made. Internal evidence suggests that the date of the survey of Bigland lands may be narrowed down to before 1799 as the map omits almost all buildings later recorded as part of the gunpowder works. It certainly pre-dates 1803 as it shows the public highway crossing the River Leven at Ford Island some 150m upstream of the present bridge site: the highway was re-routed between 1801 and 1803, for Palmer (1998, 4) notes that the Lowwood Gunpowder Company - who took over the lease of the ironworks in 1799 (section 4.2 below) - objected in 1801 when asked to contribute financially to a new bridge, while Quarter Session records (LRO QSP/2488/18-20) include authorisation of payments in August 1803 to one Thomas Hamor (?Hornor) for making plans and surveying Low Wood bridge. The survey will here be referred to as the 1796-9 Bigland estate map. Discussion of how certain of the features it shows are best interpreted - and even if others have been omitted entirely - is reserved for sections 4.2, 6.1.1 and 6.1.2 below.

4.2 Lowwood Gunpowder Works

Under the 1772 Gunpowder Act, any premises where gunpowder was manufactured had to be licensed and conform to regulations governing the form of construction and spacing of specified buildings. Licence to operate a gunpowder mill at Low Wood was granted to James King, Christopher Wilson the Younger, Joseph Fayrer and Daye Barker, on 2 October 1798 by magistrates sitting in Quarter Session at Lancaster. The full text of the licence is reproduced by Palmer (1998, 62), but in essence it permitted the four partners:

> to erect and have a Mill for making Gunpowder and proper Offices adjoining thereto at a certain Place called Low-Wood furnace otherwise called Low Wood … and also to erect and have a Magazine for keeping unlimited quantities of Gunpowder at a certain Place called Roundsea [*sic*] Gap.

The four partners' lease of the Lowwood site is dated 31 January 1799 (CRO(K) WD BGLD 2420). It was to run for 50 years, with the rent set at £220 for the first ten years and £270 thereafter, all payable by two equal annual instalments. But the partners must already have had the younger George Bigland's outline agreement to their use of the site by October 1798 in order to be in a position to apply for a licence to operate; indeed, accounts of workmen's wages dated as early as September of that year show that building work was already in train (LRO DDLO/26/1). The lease gave the partners the right:

> to erect and make any Mills Buildings or other Works for the making of Gunpowder … And also liberty to take the water out of the River Leven for the use of the said intended Works by the antient Race above the present antient Wear And … to cut Races [and] widen the Headrace on the East side.

It also conferred the right to demolish or convert existing structures on the site,

> save the Dwellinghouses and the Outhouses thereunto belonging and the Furnace and Large Coalhouse … [unless] more valuable Buildings shall be by them afterwards erected in the room of those so to be pulled down.

The partners were also granted the right 'to erect a Stove or Drying House…in Biglandwood Grounds'.

According to Palmer (1998, 12-18 and 49), buildings specifically mentioned as under construction in 1799 include the stove house and a preparing mill. The former was initially fitted with a home-made steam chest, but this proved leaky and ineffective and by November 1801 the decision had already been taken to replace it with a proprietary boiler ordered from the Manchester firm of Bateman and Sherratt. By May 1799 the company had also completed a new house at Birk Dault in Low Wood hamlet for Daye Barker to occupy as works manager.

Tyler (2002, 99-100) adds that the company incurred costs at this time constructing 'weirs, charcoal house, office and store', and was also busy erecting a store magazine. As specified in the original operating licence, the approved site for the magazine was not Lowwood but about 2.5km to the west in Roudsea Wood on the shore of the Leven estuary (Fig 2), on land rented from the Duke of Devonshire. The reason for building a magazine here so far from the main factory was not just because of the remote position, but because the place was conveniently situated for shipping lanes in the Leven estuary: vessels moored offshore could readily take on cargoes of gunpowder from the magazine for transhipment to customers directly, or indirectly via a second store magazine which the company rented at Liverpool. (The Liverpool authorities had built a long row of magazines at Liscard on the Wirral peninsula in 1753, where all vessels arriving at the port carrying gunpowder were obliged to deposit their cargo; the magazines then served as a depot where merchants collected powder for sale and export as needed (Crocker 1993, 6-10)). The company also shipped powder and imported supplies through the ports of Greenodd and Ulverston (Canal Foot) on the other side of the estuary, the latter having been connected to the sea by canal in 1796 (Fig 1).

According to the official company history written 130 years later when the works was part of ICI (Imperial Chemical Industries 1929, 340), the factory commenced operation with 'six [incorporating] mills' plus 'press, corning and other houses'. However, it is not known on what evidence this statement is based, and at least one aspect of it - namely the number of incorporating or powder mills - is contradicted by other sources. For instance, Palmer (1998, 13) refers to documents at the LRO detailing the company's search for, and purchase of, a suitable shaft for their powder mill. Although it is not clear what this shaft was needed for (it could have been either an axle for the waterwheel, or a drive shaft for the incorporating machinery), the implication is that the works started production with only a single powder mill - or at most a pair of mills situated either side of a single wheel - not the six alleged. Even a quarter of a century later it seems that production levels had not risen significantly, for on 24 March 1826 David Huddlestone, founder of the rival Elterwater Gunpowder Company, wrote to his agent, Mr Hyde, saying that he had 'only one Mill at work…the Low Wood Co…3 mills and Mr Wakefield [owner of the Old Sedgwick/Basingill complex] 4' (CRO(K) WDY 448). It may be that the ICI historian misunderstood whatever sources were available to him, and interpreted a similar reference to three mills at Lowwood as meaning three pairs of mills, *ie* a total of six. But as the Elterwater and Basingill factories are known from other evidence to have had only one and four mills in 1826, not two and eight (Jecock *et al* 2003, 16; Hunt and Goodall 2002, 40), Huddlestone's reference to three mills at Lowwood must be taken at face value. It is likely that the three mills were all in place as early as 1803, for Palmer (1998, 55) records that the company was trying to get new mills up and running in the early part of that year to take advantage of the fact that Wakefield had been temporarily put out of business by the failure of his weir at Old Sedgwick.

The company initially sourced all its raw materials from external suppliers. Saltpetre imported from the Asian sub-continent by the East India Company, was bought at auction in London and transported to Liverpool by sea or canal, while sulphur was imported directly to Liverpool from Italy; both were then shipped north to Lowwood in coastal-trading vessels. Charcoal was purchased locally. Of the three, it was normally only saltpetre (and, occasionally, sulphur) which required further processing on-site before use, and it seems that the company employed an old boiler acquired from the previous lessees of the site to perform these tasks (Palmer 1998, 15-18). In August 1801, the company took the decision to start manufacturing its own charcoal, and purchased from the London firm of Gilbert Handsyde, two cylinders for producing charcoal by the cylinder or retort method. This proved so successful that three more cylinders were purchased in May 1802 from John Wilkinson of Bersham. The reason for the switch to in-house production appears simply to have been in order to improve the quality of the company's powder: Major William Congreve the elder, deputy comptroller of the Royal Laboratory at Greenwich, had demonstrated experimentally as far back as 1785 that cylinder charcoal made stronger gunpowder than charcoal produced by the traditional method of burning in clamps (Cocroft 2000, 30 and 43; Tyler 2002, 104). The change presumably necessitated the construction of sheds to house the retorts and supplies of coppice wood. Another new erection at this time may have been a fire-engine shed, for after a series of relatively minor flash fires and explosions in the first few years of operation, Wilson suggested in 1802 that the company acquire and station its own fire engine at the works (Palmer 1998, 47-8).

Tyler (2002, 98) implies (although without citing direct evidence) that the extant weir at the very top end of works (which by the first quarter of the 20th century was known as Eel Dams although there is no evidence for the earlier currency of the name) plus the long headrace leading from it, were also both constructed in 1799 as part of the company's initial development of the site. At first sight the assertion appears to be borne out by cartographic evidence, for both features are depicted on the series of maps and plans of the gunpowder works dating from the mid-19th to early 20th centuries (Figs 4-9), but seemingly not on the 1796-9 Bigland estate map (Fig 3) showing the earlier ironworks. However, close inspection of the latter document suggests that what could easily be mistaken for a track running in a straight line north from the road over old Low Wood Bridge to the sharp westward bend in the river near the top of the map, should rather be interpreted as a leat channel: after all, a track in this position (apparently leading nowhere) makes little sense, and the depicted feature corresponds very well to the middle and lower course of the gunpowder headrace shown on the later maps. Against such an interpretation is the fact that no weir is shown at the feature's northern end where it meets the river, but this may be explained by the report of the ironworks weir as broken down in 1798 (section 4.1 above). In short, a weir at this location may simply have been too ruinous to portray when the map was surveyed. If the above argument is accepted, it means that in 1799 the gunpowder company replaced an existing but ruinous weir (?Stang End) with a new one (Eel Dams) about 200m upstream, and extended the existing headrace accordingly. Such an interpretation of the evidence certainly makes sense of clauses in the 1799 lease (this section above) granting the gunpowder company the right to use the existing 'antient' race and weir, and to widen the headrace 'on the *East* side'. (This last clause presumably refers to a headrace situated on the east side of the site, and is not merely granting permission to widen an existing headrace towards the east).

It would seem reasonable to equate the postulated ruinous weir with the Stang End weir referred to in earlier documents, which the iron company were anxious to keep operational and in good repair (section 4.1 above): certainly 19th-century OS map evidence (*eg* Figs 7 and 8) records the name Stang End in association with woodland on the opposite bank of the river to the weir site here proposed. However, the ascription of the name cannot be completely certain, for the Bigland estate map portrays a second weir (this time without any trace of an associated leat leading from it) a few hundred metres downstream towards old Low Wood Bridge. Whilst it could be argued that both weirs belonged to the ironworks, with the upper (?Stang End) weir providing power to the blast furnace and the lower unnamed weir power to the associated forge (as suggested by Bowden (section 4.1 above)), such an interpretation is contradicted by a letter which two of the gunpowder partners exchanged in March 1799, in which Wilson informed Barker that Mr Holmes (a walling contractor) 'wishes you to puddle more of the headrace and to begin at the lower part of the race *to the forge*' (quoted by Palmer 1998, 13). This raises the very real possibility that the lower of the two weirs is actually that built to supply the, earlier, 17th-century Burnbarrow forge. Furthermore, if the eastern headrace did indeed power both 18th-century furnace and forge as here suggested, the most likely arrangement is for the race to have bifurcated somewhere near the furnace, with a subsidiary channel

leading to the forge. The implications of this argument are examined in more detail in sections 6.1.2, 6.2.1, 7.1 and 7.2 below.

On the basis of the available evidence, therefore, it seems that when, or shortly after, the factory opened for business in late August 1799 (Palmer 1998, 18), it consisted of a manager's house, offices, various stores, saltpetre refinery, charcoal-retort house, preparing mill, between one and three incorporating mills, press house, corning house, stove house, fire-engine shed, and store magazine; power for these buildings (where required) was apparently drawn from a new weir (Eel Dams) supplying an extended headrace. It is unclear at what date the works acquired its own cooperage (Tyler 2002, 98), but right from the outset there would necessarily have been a packing or heading-up house where powder could be put into barrels. A number of other buildings typical of a fully-developed powder works, such as a charge house, glazing house, dust house, expense magazine, sawmill and watch house, which are not specifically documented, may perhaps be presumed.

Whatever the initial size and layout of the factory, the gunpowder company quickly prospered and expanded. All external loans had been repaid by 1806 (Palmer 1998, 6), while the 1846 plan (this section below and Fig 4) shows that some 50 years after the works had opened, the original stock of buildings had increased to include two corning houses, two drying houses, and fourteen incorporating mills. The dates and stages of this expansion are difficult to ascertain, but since we have already seen (this section above) that as late as 1826 the works possessed only three incorporating mills, most of the development is likely to have taken place after this time.

This would appear to be borne out by an indenture of December 1827 (CRO(K) WD BGLD 2420; LRO DDLO/34/3; site deeds, While Estate Trustees Collection) which in return for a one-off payment of £2000 conferred on the then surviving partners in the business, Barker and Wilson, the right to a 50-year extension on the lease with all existing rights and privileges upon expiry of the original term in 1849. The indenture is strong evidence that Wilson and Barker were confident in the continued success of their business and were perhaps thinking about starting to expand production capacity. According to Tyler (2002, 116-17), however, it was actually Barker's sons, Daye II and John (who succeeded their father in running the business when the latter died in 1835) who really drove the business forward. Tyler states that the brothers paid a further £2000 to transfer the lease into their own names, and straightaway invested in a second store magazine at Roudsea, completed in September 1836. However, no indenture recording the transfer of the lease survives amongst the site deeds, and its existence is inherently unlikely as both the original 1799 lease and 1827 renewal already permitted the lease to be inherited by the named parties' 'executors, administrators and assigns'. Tyler also implies that very soon after inheriting the business the brothers sought advice from William Sealy, manager of the Tonbridge gunpowder mills, and used his advice and trade connections to diversify away from their traditional stock-in-trade (blasting powder) into the manufacture of higher-quality products, namely military-grade and sporting powders. However, EH has found no evidence specifically linking Sealy to Lowwood before 1859 (HF LW/1850/014), and apart from a possible contract to supply military-grade powder to the Board of Ordnance in 1854 (HF LW/1850/007-11), the available

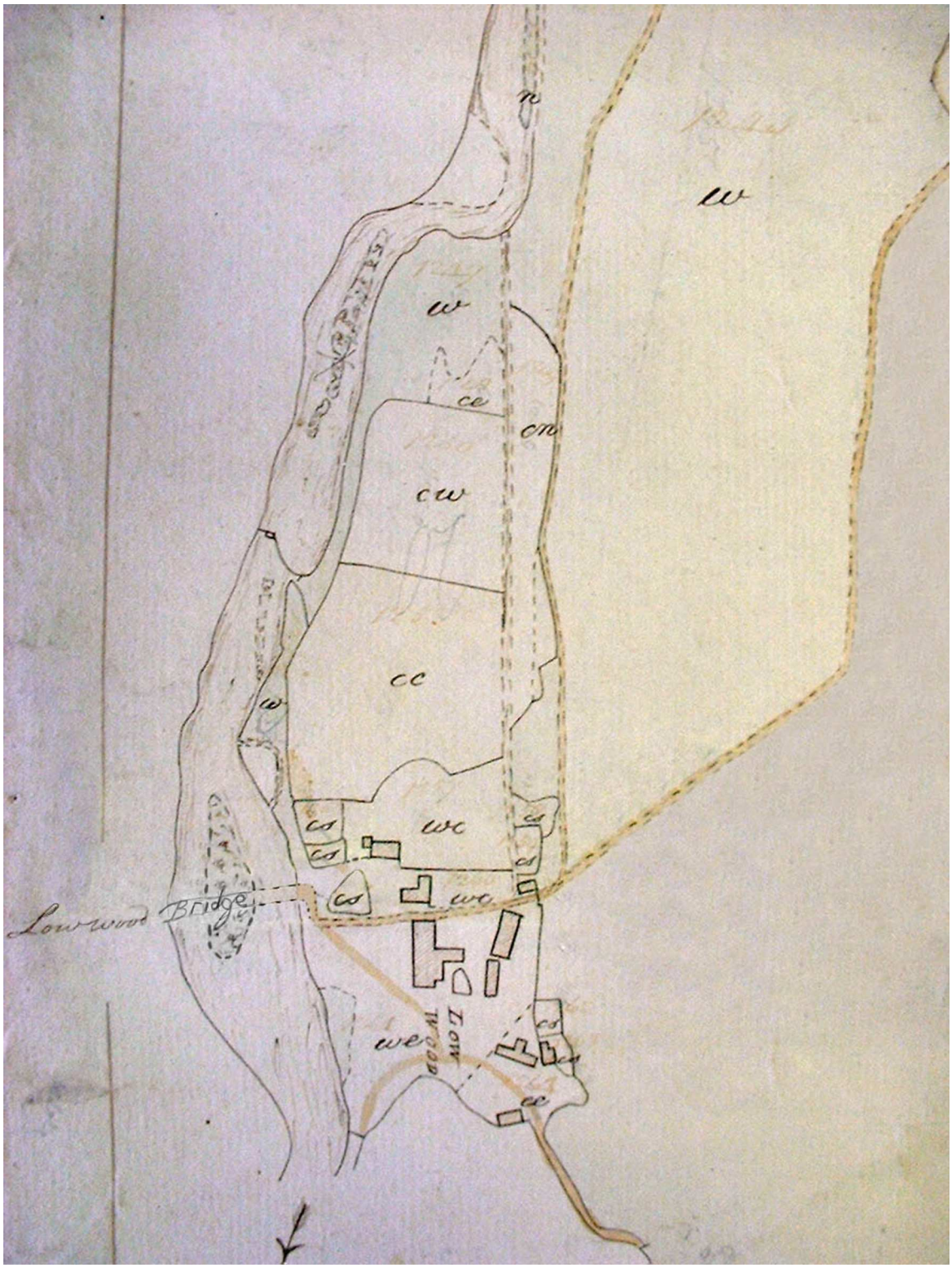


Fig 3. Late 18th-century plan of Lowwood Ironworks ('the 1796-9 Bigland estate map'). (Extract from CRO(K) WPR/89 PR/2716/9, copyright reserved)

evidence suggests that attempts to win military contracts from the British government did not begin in earnest until 1862 (this section below). In 1845, Christopher Wilson the Younger, the longest-lived of the four original partners, died at the age of 81 (Tyler 2002, 109).

What has already been referred to above as the 1846 plan was commissioned by the Lowwood company in response to proposals by the Furness Railway Company to construct a branch line along the Leven valley. The economic rationale for the new branch was not primarily goods traffic, but the burgeoning trade in conveying sightseers and day-trippers to and from Windermere (Joy 1983, 215). Three versions of the plan are known, differing only in minor detail; that reproduced here (Fig 4) is in the private possession of Ron Mein. The gunpowder company was fearful that the intended route passed too close to their works, and either that stray sparks from locomotives might carry on the wind and cause an explosion, or a large explosion at the works would threaten life and property on the railway. There had already been one such explosion at Lowwood in 1823 when what is described on the plan as the higher corning house blew up and damaged the Low Wood Inn 143 yards (130.7m) away, as recorded in the key. The plan does not identify all buildings depicted, but those it does name are, in order from south to north, a counting house and saltpetre refinery close to Low Wood hamlet, plus (lying mostly between the river and the headrace) a preparing mill, charge house, fourteen gunpowder mills arranged in seven pairs, dusting house, lower drying house, packing room, lower corning house, upper drying house, higher corning house and magazine. Interestingly, no press or glazing house is named. The headrace is depicted feeding subsidiary leats taking power to individual process buildings, before returning to the river north of the saltpetre refinery; water in the subsidiary leats must have returned to the river via a network of covered channels since no tailraces are portrayed leading from the process buildings. Strangely, the plan does not show a weir associated with the headrace, but this must be a straightforward omission as the race could not have functioned without one. The plan also shows the unnamed weir further downstream first depicted on the 1796-9 Bigland estate map, again apparently disused. Both weirs are depicted on the Ordnance Survey (OS) first edition 6-inch map of the area, surveyed only two years later in 1848 (Ordnance Survey 1851). Otherwise, the OS depiction of the works matches that of the 1846 plan exactly. In the event, proposals for the branch line whose construction occasioned the 1846 plan were put on hold for another 20 years (this section below).

The company's initial 50-year lease of the site expired in 1849, but the 1827 indenture had already ensured the company a 50-year renewal. The Barker brothers chose to mark the company's fiftieth anniversary, however, by rebuilding what remained of the old blast furnace which they had previously converted into a saltpetre refinery, creating a new purpose-built refinery replete with 40-foot tall clock tower in its stead (Tyler 2002, 117). This is borne out by two stones bearing the date 1849 set into the facades of the surviving building. Despite being rebuilt, the new complex essentially replicated the footprint of the earlier building (compare Figs 3, 4 and 6).

Very little primary material survives charting developments at Lowwood in the 1850s. Letters in the HF collection ostensibly span the period 1850 right through to 1925, but the majority date to the 1860s and later. One useful source for the decade, however, is the 1851 census which shows that Birk Dault in Low Wood hamlet was then occupied by Daye Barker (*ie* Daye II), described as 'Managing Partner at a Gunpowder Works, empl[oying] 63 men'; he is also listed as unmarried and aged 59. It is not possible to identify all 63 workers at the

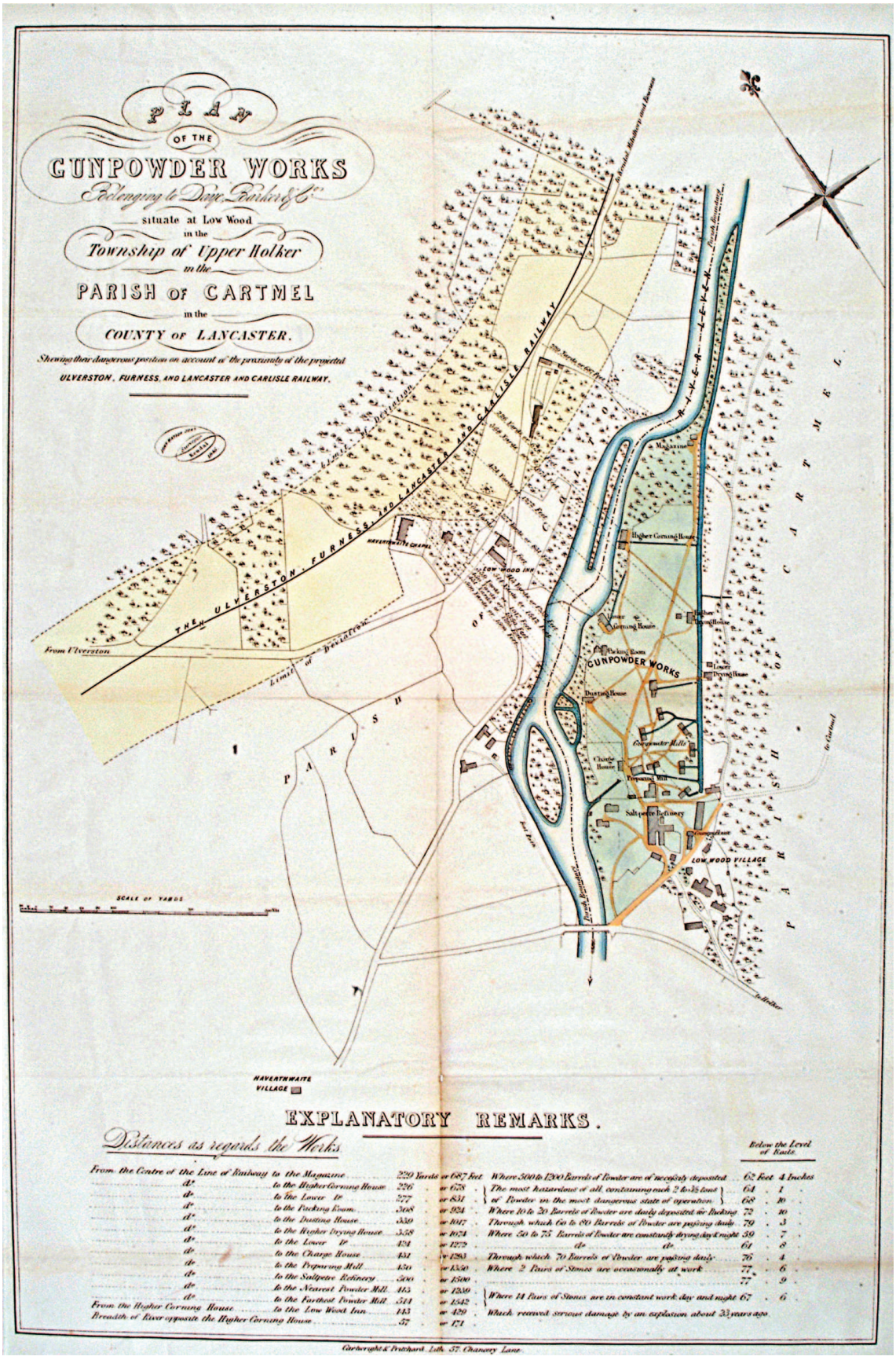


Fig 4. Plan of Lowwood Gunpowder Works produced in connection with the proposed Leven Valley Branch Railway ('the 1846 plan').
(Ron Mein Collection, copyright reserved)

factory from the census returns, but 22 gunpowder makers (one retired), grinders, pressers, packers or labourers, plus two gunpowder clerks, two saltpetre refiners and a brimstone refiner, are all listed as resident at Low Wood itself or the nearby settlements of Backbarrow, Brow Edge, Trundle Brow and White Gate (Fig 2); a number of coopers and a sawyer living in these settlements are also likely to have plied their trade at the works (Cumbria Family History Society 2003, 94-113). Other workers probably lived at Haverthwaite.

In 1857 the Ulverston and Lancaster Railway Company completed its viaduct across the River Leven, finally linking Ulverston and Barrow-in-Furness into the national railway network. Freight charges on the railway were initially dearer than sea-borne carriage, but the new viaduct quickly proved a major obstacle to vessels in the estuary and also caused the shipping lanes to begin to silt and change course, prompting the Lowwood company to negotiate its own railway siding at Cark, the nearest station on the new line some 9km south of the factory (Joy 1983, 106-11; Tyler 2002, 117-18). Since the Roudsea magazines were inconveniently situated for Cark station, the company decided to construct a new magazine at 'Busky field' close to the works. Tyler (2002, 123) implies that this Busky magazine was not built until 1865, but it is included on a plan of 1863 (this section below) and correspondence points to it being proposed as early as 1860 and operational by June 1861 (LRO DDX 116/14; HF LW/1865/009-10). The confusion may stem from an investigation into the magazine's siting made about 1865 by a government inspector, Lieutenant-Colonel Boxer, following a complaint by people living nearby (*Westmorland Gazette*, 5 Dec 1868). Despite the coming of the railway, the company continued to export gunpowder by ship from Roudsea until at least 1879 when the company considered constructing a pier 200 yards (182.8m) long out into the navigable channel in order to allow vessels to load regardless of the state of the tide (HF LW/959/008). However, the proposal was not taken forward. The Ulverston and Lancaster Railway became part of the Furness Railway Company in 1862.

In 1859, Daye Barker II died. Tyler (2002, 117) states that his son, Daye III, entered the business alongside his uncle John, but this seems unlikely given that census records give Daye II as unmarried and childless in 1851 (this section above). Daye II's death may have been the occasion of William Sealy's appointment to the position of works manager at Lowwood, however, for the first mention of Sealy's name amongst documents in the HF archive is in July of that year (LW/1850/016). Other sources show that the company was investing heavily in plant and buildings at this time. In addition to the Busky magazine already mentioned, the ICI historian states that new corning machines were installed in 1859 (Imperial Chemical Industries 1929, 340) - apparently supplied by the London firm of Hopkinson & Cope (HF LW/958/137) - while letters in the HF archive dated July 1859 (LW/1850/014 and 016) record proposed alterations to the 'old stove house' to accommodate a larger boiler and new chimney, and indicate that replacement gearing machinery was also on order for the mixing (preparing) house. In November of that year, the company spent an additional £127 18s 2d erecting a new 'crushing house' (?preparing house) (HF LW/1850/017 and 018). Shortly after, in June 1861, they signed a 38½-year lease with the Bigland estate for a thin strip of woodland adjacent to the River Leven which apparently had not previously formed part of the works (site deeds, While Estate Trustees Collection). Included

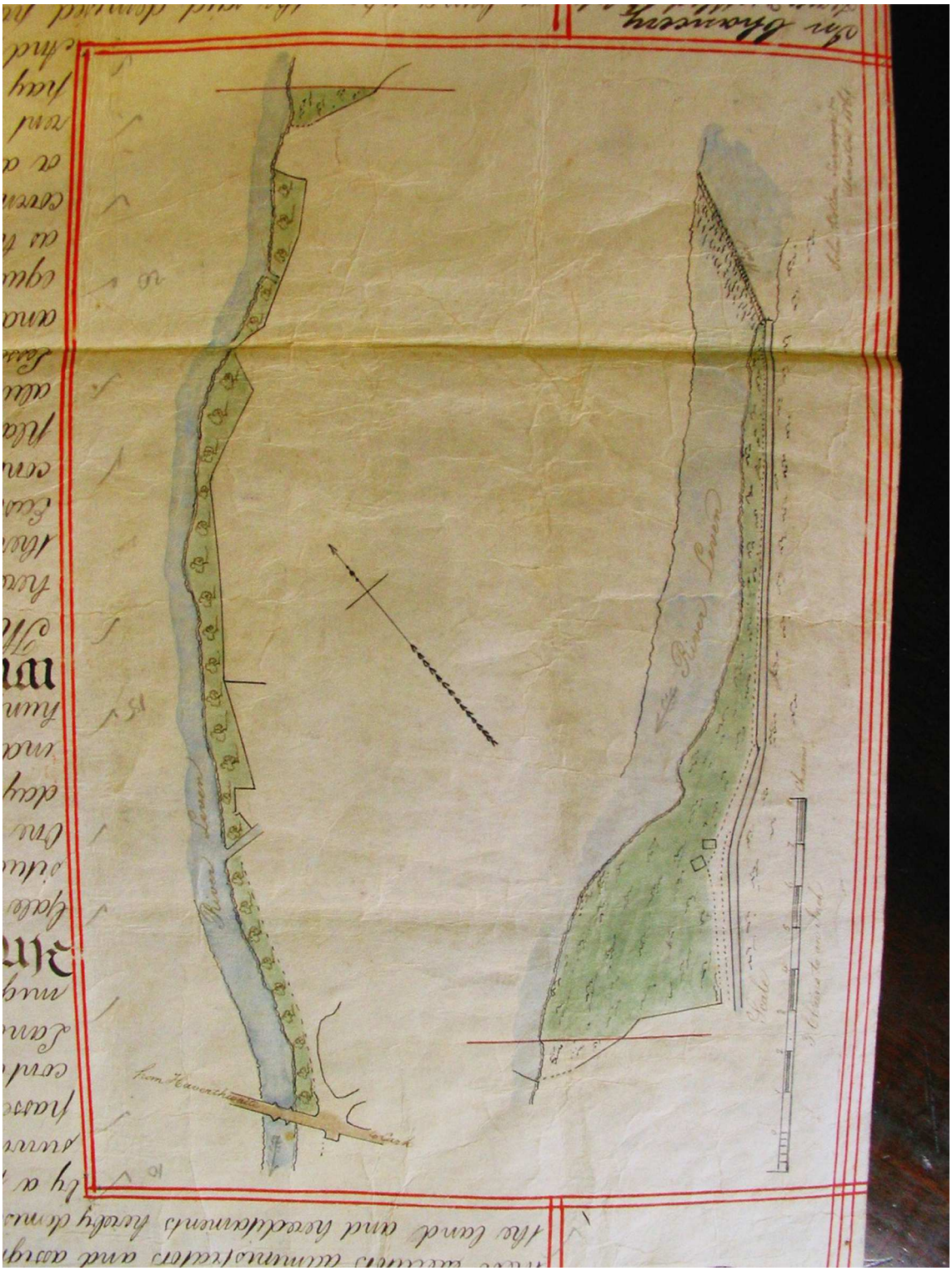


Fig 5. Plan of land leased by the Lowwood Gunpowder Company in 1861 ('the 1861 plan').
(Extract from site deeds, copyright reserved)

in the lease is a plan delimiting the land specified (Fig 5). Comparison between it and later plans reveals that the reason for acquiring the extra land was in order to develop it for new buildings requiring waterpower and/or isolation: a new reel and glaze house, press house, corning house, boiler house, expense magazine and heading-up house had all been erected on it by 1863 or shortly thereafter (this section below, and compare Figs 4 and 6). A few

days after signing the lease, the company also ordered a 12-inch (304.8mm) hydraulic press from Hopkinson & Cope, price £197 10s 0d, although the pump cylinder fractured within a year of being installed (B Patrick collection).

Contra Tyler, it seems that it was only in 1862 that the company began to compete in earnest for government contracts, most likely because following the recent improvements, the factory was now equipped to meet higher levels of production; it was rewarded with an order to supply 2000 barrels of gunpowder (HF LW/1862/*passim*). No sooner had the contract been received, however, than a serious fire destroyed one of the mixing houses and two of the incorporating mills (*Westmorland Gazette*, 8 Mar 1862) - undoubtedly the catalyst for the company's subsequent purchase of a second fire engine and 120 feet (36.58m) of leather hose from the firm of Messrs Shand & Mason of London on 3 June (HF LW/958/178 and 181). Tyler (2002, 119) says that following the fire John Barker wrote to Thomas Howell at the War Office informing him of the damage to the works and the possible impact this would have on the company's ability to fulfil its contract, but either this letter is not part of the HF archive, or else the statement arises from a confused reading of a letter Barker actually sent on 16 February 1863 (HF LW/1863/005) in response to a request for information on an accident which occurred some months later.

In late January 1863 a disastrous explosion ripped apart the glazing house and spread to two corning houses and a press house, leaving six men dead. Local press coverage reveals that the glazing house and one of the corning houses stood adjacent to each other either side of a central wheel-pit, while the second corning house lay about 90 yards (82.26m) away 'separated by trees and an embankment'; the press house stood about 45 yards (41.13m) from the latter building, separated from it 'by trees, a plantation, a wall twelve feet (3.66m) high and an embankment about eight feet (2.44m) high', and contained enough powder to propel the press-head right across the river (*Westmorland Gazette*, 7 and 14 Feb 1863). Contracts were let almost immediately to start rebuilding and re-equipping the damaged buildings: 10-inch (254mm) and 12-inch (304.8mm) presses were operational at the low press house by the end of April (HF LW/1863/036), while the repaired corning and glazing houses were reportedly up and running by late August (HF LW/1863/138 and 162). But the catastrophe so affected John Barker that he resigned from active control of the business and transferred ownership to the new, Liverpool-registered, Lowwood Gunpowder Co Ltd, in which he retained a majority share ownership. William Sealy left the company's employ, and was replaced as works manager by John Dodgson; William Briggs became company secretary (Imperial Chemical Industries 1929, 340; Tyler 2002, 121). The indenture for the sale of the business to the new company is dated 1 July 1863 (site deeds, While Estate Trustees Collection), and has annexed to it a detailed site plan showing the buildings which (purportedly) then existed (Fig 6). The indenture will henceforth be referred to as the 1863 indenture, the plan as the 1863 sale plan. However, the latter document must be treated with some caution, as explained below.

As already mentioned, Barker sent a letter to the War Office in February following the explosion. This was accompanied by a rough sketch of the part of the works affected. That sketch does not survive, but by combining clues in the letter with information in the press

reports and the disposition of buildings shown on the 1863 sale plan (Fig 6), it is possible to suggest that the explosion originated in the glazing house which the latter document depicts adjacent to the river in the centre of the site. On the 1846 plan (Fig 4), this same building is described as the 'Higher Corning House', but at the time of the explosion it seems that the two halves of the building north and south of the wheel-pit were in use as separate corning and glazing houses, as described in the press report. It was only in April 1863, three months after the explosion, that the decision was taken to convert the whole building to glazing (HF LW/1863/035) - hence its description on the sale plan a few months later. If correct in this identification, the scenes of the other explosions are probably the buildings described as 'Granulating (*ie* corning) Ho[use] No. 1' and 'Press Ho[use]', which the same plan shows both stood south-west of the combined glazing/corning house. The former lies *c* 75m from the site of the initial explosion, the latter some 62m further on again. Although the second distance in particular is not a close match for the detail in the press reports, internal evidence in the Barker letter confirms that all the damaged buildings were located towards the southern end of the works, for the lost sketch reportedly showed two pairs of incorporating mills.

Following the decision to convert the damaged corning/glazing house (formerly the higher corning house) to glazing only, the Greenock firm of John Hastie & Co was awarded the contract for supplying new machinery: three glazing barrels were to be placed either side of the central waterwheel, powered by external gearing (HF LW/1863/035). An annotated sketch plan of a mill building - unnamed but seemingly the former higher corning house - dated 8 May 1863 (HF LW/Misc/074, reproduced here as Fig 59), talks of the power of that house's waterwheel being sufficient to turn 'six glazes at 15 turns per minute'. In June, Charles Blades of Lancaster was engaged to re-roof the building (HF LW/1863/046). The company initially considered employing corrugated iron for the roof rather than the wood or slate traditionally used (HF LW/1863/028, 030 and 031), but it is unclear if they proceeded with the idea. Hastie & Co won the contract for supply of new corning machinery also, but delivered late as they did with the glazing barrels, and incurred fines (HF LW/1863/240).

The 1863 indenture and sale plan are potentially very useful documents in that between them they seem to identify the function and location of every building then existing at the works, and also list property the company owned elsewhere. The schedule which forms part of the indenture itemises the old company's built and mechanical assets as follows: seven pairs of amalgamating mills; reel and glaze houses (new); heading-up house (new); two stoves (one new); two expense magazines (new); press house, pump house and machinery (new); two mixing houses and machinery (new); saltpetre refinery complete; four coopers shops (two new); new store magazines; two store magazines at Roudsea; magazines at Liverpool, Erith, Penkridge, Newport and Bolton; sawing house, turning shop and machinery; carpenters shops; three offices (one new); saltpetre warehouse and tramway; three cylinder houses; packing shop and boiler house; proof houses and mortar; fire-engine house, cask house, charcoal, wood, and budge loft warehouses; boiler and shed and charge houses; two old magazines; old store; small engine shed; watch houses; and sieve house. In addition, the indenture states that the old company possessed two fire engines and two railway

vans, which were to be passed on to the new company 'at valuation'. The sites of most of these buildings are readily identifiable on the accompanying sale plan, although not always labelled in exactly the same way. For example, the plan does not name the 'proof houses and mortar' listed in the schedule, but shows instead two 'Gun[s]' situated at one end of a 'Proof Ground' or testing range. Such ranges were a requirement of military contracts which demanded the strength of the manufactured powder be proved. Tyler (2002, 117) states that the factory was testing its powder this way as early as 1839, but no proofing range is shown on either the 1846 plan or OS first edition 6-inch map - further evidence perhaps that, as suggested (this section above), the company did not actually compete for military contracts before 1862. Other detail on the sale plan builds on information in the schedule: thus the plan shows that the tramway recorded in connection with the saltpetre warehouse ran between it and the northern end of the saltpetre refinery.

However, the plan must be treated with some caution, as it appears to contain errors both of commission and omission. In some cases these may simply be mistakes reflecting the speed with which the document was drawn up: for example, the cooperage immediately south of the saltpetre refinery is depicted at 90° to its orientation on both earlier and later maps, while neither the sawmill nor its leat (which departed from the main headrace opposite 'Drying House No. 1') is shown, even though both these features existed in 1846 and re-appear on later maps (compare Figs 4 and 7). Discrepancies between the sale plan and the schedule are harder to explain. For example, the plan depicts two granulating houses although none is mentioned in the schedule, and two press houses whereas the schedule lists only one. The absence of 'Granulating Ho[use] No. 1' from the schedule is perhaps explicable by the fact that the building had been repaired following the explosion but still lacked machinery (it was not operational until August – this section above). But surviving company correspondence indicates that 'Granulating House No. 2' and 'Press Ho[use] No. 2' situated at the head of the race in fact only existed at the drawing-board stage when the plan was made, and were not built, fitted out and operational before 1864-5 (*eg* HF LW/1863/147, 195, 250 and 252, HF LW/1864/021, 029, 037 and 172, and HF LW/958/075 and 111). These 'second' houses seem to have been intended as reserve capacity for use in periods of high demand or when the principal houses were out of action because of maintenance or repair. The corning machinery for the second granulating house (plus the press-house pumps) was again supplied by Hastie & Co, but this time the press was bought from the firm of Fawcett, Preston & Co, not Hopkinson & Cope as in 1861.

Tyler (2002, 121) implies that it was at this time immediately after the 1863 explosion, that a Robey boiler, manufacturer's no. 19420, was installed in the boiler house heating the lower stove house, but as this particular machine was not built until 1899 (information from D Davies, Robey Trust), this is plainly impossible.

On 21 October 1863, the company bought 5 acres (2.025ha) of land at Stang End opposite the works for £455 (HF LW/1863/211-12; site deeds, While Estate Trustees Collection). The purchase should probably be equated with all or parts of the four parcels of land numbered 1578 to 1581 on the OS first edition 25-inch map (Ordnance Survey 1890a, reproduced here as part of Fig 7; hereafter referred to as the OS first edition 25-inch). The impetus for the

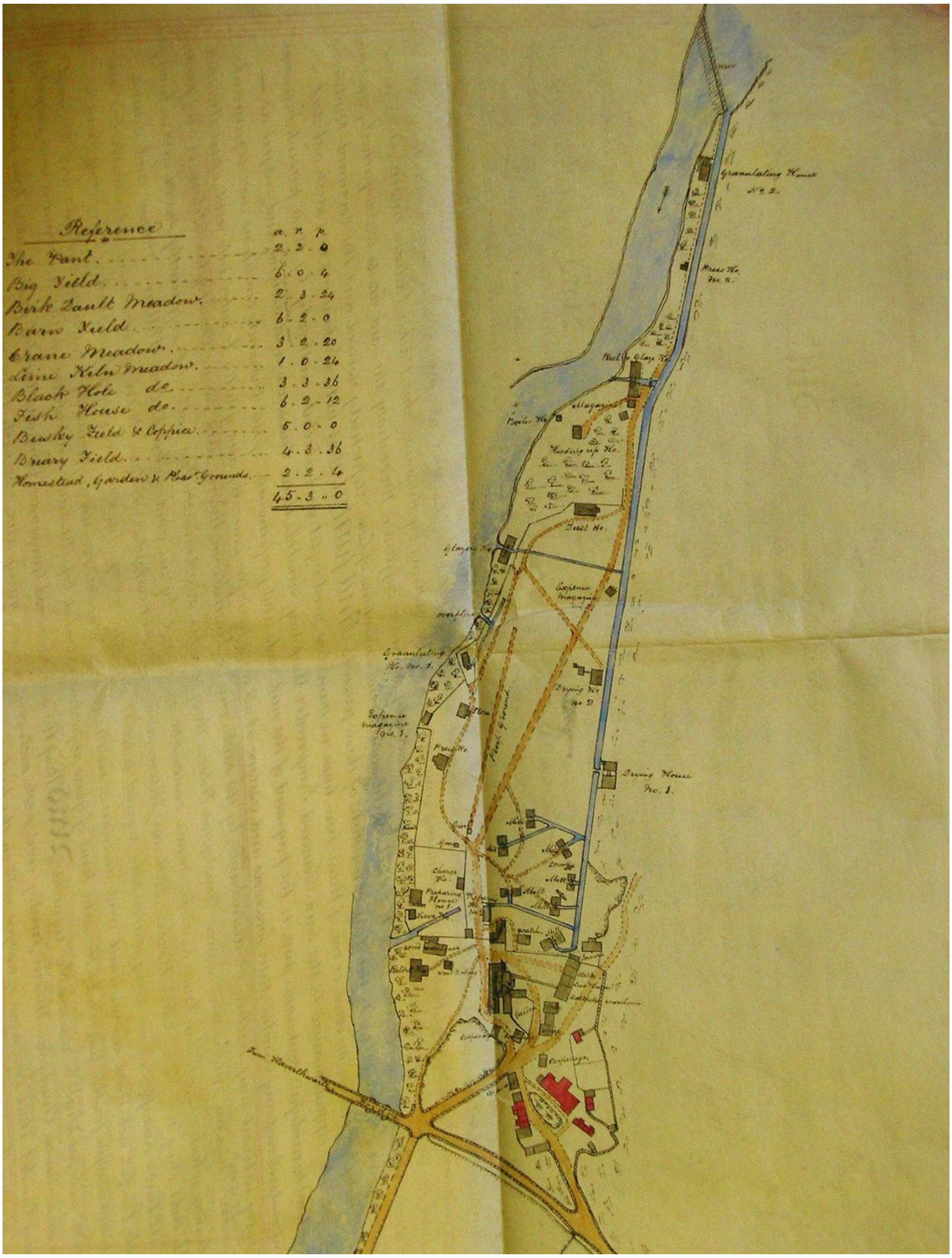


Fig 6. Detail of the plan of Lowwood Gunpowder Works accompanying the 1863 sale indenture ('the 1863 sale plan'). (Extract from site deeds, copyright reserved)

purchase may well have been the Furness Railway Company's reconsideration that year of a proposal first mooted in 1846 (this section above) to construct a branch line along the Leven valley to the southern end of Windermere, for the newly acquired land would give the Lowwood company direct access to the likely route of the proposed railway. However, when in 1865 the Furness Company confirmed its intention to proceed with the new route (Joy 1983, 215), John Dodgson's first thought on behalf of the Lowwood company was to construct

a ‘light’ (or narrow-gauge) tramway within the works, and to link it to the branch by a ‘heavy’ (or standard-gauge) tramway which would leave the branch south-west of Haverthwaite village (Fig 2), cross the river ‘between the black hole and the fish house’, and run past the Busky magazine to end at the saltpetre refinery (HF LW/958/097). Shortly after, as further details became known, including, it seems, the proposed position of Haverthwaite station, Dodgson put forward a revised scheme which involved a direct link to the station across the company’s Stang End property (HF LW/958/104). In the event the new line opened for freight in April 1869, and the following month the company authorised Richard Reynolds, Dodgson’s successor as works manager, to proceed with construction of a tramway (HF LW/1869/025), although the precise layout is not recorded. The earliest plan depiction of it is that on the OS first edition 25-inch map, surveyed in 1888 (Ordnance Survey 1890a and c; see Fig 7). Tyler (2002, 131) seems to assume that Dodgson’s proposal to build one tram line crossing the river to connect with Haverthwaite station directly (as shown on the first edition map) was taken up straightaway, but other evidence suggests that this part of the system was in fact not constructed until 1883/4 (this section below).

Before then, on 28 November 1868, another serious explosion at the works had devastated one of the corning houses and left the five men working inside dead. The local newspaper report of the ensuing coroner’s inquest (*Westmorland Gazette*, 5 Dec 1868), states that the force of the explosion blew the walls and roof of the building completely away and upset and damaged the corning machinery whilst leaving the waterwheel unscathed. The report does not state which of the two corning houses was involved, but subsequent correspondence preserved in the HF archive suggests that it was the main or low house (‘Granulating Ho[use] No. 1’ on Fig 6). As with the previous fatal accident in 1863, death at the factory seems to have been the catalyst for management changes, and in January 1869 Richard Reynolds replaced John Dodgson as works manager. Reynolds had no previous experience of the powder trade, but was a civil engineer by training and a good friend of J C Wilson, shareholder in the company and presumably a relative of one of the original founders of the business, Christopher Wilson the Younger. Reynolds seems to have spent much of the first few months of his appointment visiting other gunpowder factories and examining alternative designs of corning machinery, seeking ways of reducing the number of men needed to operate the Lowwood plant. By February, plans for new machinery which needed only two men to work it unlike that in the previous corning house which required five, seem to have been well advanced and in May the company directors gave approval to start work erecting a replacement building on the same site as the old one (HF LW/1869/001, 004-6, 011-14, 017, 018 and 025). However, the new machinery proved more difficult to install and perfect than hoped: it was only trialled in late April 1870 and was reportedly still giving teething problems almost a year later (HF LW/1870/007, 009 and 010; HF LW/1871/007).

On 8 March 1871, the reserve or high corning house also exploded. The timber and slate superstructure of the building was blown totally away, the machinery inside badly damaged, and the four men working it all killed (*Westmorland Gazette*, 11 and 18 Mar 1871). The contract for supplying new machinery was again won by Hastie & Co in August of that year, although installation was reportedly still not complete in April 1872 (HF LW/1871/008, 011,

015 and 030; HF LW/1872/001 and 005). Fortuitously, two days before the explosion, the company had completed the purchase of the land on the opposite bank of the river upstream of the weir (site deeds, While Estate Trustees Collection), thereby extending the safety exclusion zone around the factory.

If Reynolds spent much of the first three years of his tenure as works manager dealing with the aftermath of fatal explosions, by 1872 he was also developing plans for modernising and expanding the works in other ways. For example, early in 1872, the company sought to acquire a turbine. Tyler (2002, 132) states they accepted an offer from a William Turnbull of Newcastle-upon-Tyne to sell them a second-hand but unused 'Vortex' 10bhp (7.5kW) turbine made by Williamson's of Kendal, but other correspondence shows the company also approached the firm of Williamson's direct and received costings for 20bhp (14.9kW) and 7bhp (5.2kW) versions, both of which they seem to have bought (HF LW/1872/002-4); it is not reported, however, for what purpose either was intended. Reynolds had by this time also presented his directors with a proposal to relocate the sawmill and erect four new incorporating mills in its place. In May of that year he submitted detailed costings, but the board took fright at the price which had escalated from an initial estimate of £1500 to a final bill nearer £4000, and declined to authorise the expenditure (HF LW/1872/008 and 017). In 1873 and 1875, the company experimented with manufacturing compressed gunpowder pellets on a small, simple hand press made out of wood and brass, which could turn out five pellets at a time (HF LW/959/146).

The passage of the Explosives Act of 1875 which set up Her Majesty's Explosives Inspectorate and for the first time brought all gunpowder factories under a strict régime of government inspection and control, required Lowwood to apply for a continuing licence (Public Statutes General 1875, 153-5). The works was duly issued with continuing certificate no. 23 on 22 April 1876 (Explosives Inspectorate 1887, 3), but errors in the licence and discrepancies in working practice were still being identified and resolved as late as June 1880 (HF LW/959/032). In the interim, Reynolds had resigned as works manager, and was succeeded in October 1879 by James Collinson (Tyler 2002, 133; HF LW/959/001). One of Collinson's first concerns was to embark on a tour of the north of England to try and boost the company's falling sales; another was to oversee the introduction of cartridge manufacture to the works, for the 1875 Act had made their production illegal except on licensed premises. The company initially tried to sell paper cartridges filled with loose powder, but produced its first compressed cartridges in February/March 1882 (HF LW/959/180-1).

Despite Collinson's best efforts to drum up trade, in 1882 the board of directors decided to sell the business to their local rival, W H Wakefield & Co, for £8000; the conveyance is dated 20 November (site deeds, While Estate Trustees Collection). Despite the change in ownership, the works continued to trade as the Lowwood Gunpowder Company (Explosives Inspectorate 1887, 3).

The new owners embarked on a programme of immediate improvements to the factory. Although details are imprecise, it seems that application was being made to HM Explosives Inspectorate for an amending licence covering changes made to the layout of the factory

and/or function of buildings as early as April 1883 (HF LW/959/237). By May, improvements to the cartridge press had eliminated the need for men to work overtime operating it (HF LW/959/239), and in July, the new company was considering how it might best effect a direct link to the Furness Railway Company's Windermere branch line. The old Lowwood company had apparently had an agreement with the railway to construct a siding at Ladysyke (Fig 2), but the cost of this was now said to be prohibitive as recent Board-of-Trade regulations had placed controls on the use of facing points (HF LW/959/248; site deeds, While Estate Trustees Collection). To get around this, the Lowwood company resurrected John Dodgson's proposal made back in 1865 (this section above) to connect the works to Haverthwaite station by a tram line running up through Stang End. They seem also to have proposed building a link out to the Busky magazine. Neither extension is referred to directly in any surviving documention seen by EH, but the construction of both at this time is implied through dealings the company had in October 1883 with the Cartmel Highway Board, the ratepayers of Colton, and the Quarter Sessions Court, seeking permission for the two lines to cross the public highway; these papers record that the gauge of the system was 3 feet 6 inches (106.7mm) and that it was horse-drawn (HF LW/959/255, 258, 259a and b; LRO QSP/4159/15, 16 and 18; site deeds, While Estate Trustees Collection). At least one of the lines had been completed by early 1884, for a letter written by Collinson to J W Weston, his new boss at Gatebeck, in September of that year recites items from the half-year account of a certain T Ellen, which amounted to £8 16s 6d 'since opening of Tramway' (HF LW/959/278); this may have been the link to Haverthwaite Station, for on 16 April the company had purchased 785 square yards (656.35 square metres) of land 'being part of Stang End Wood…and also a piece of Bleaberry Holme Island' from Frederick Barker for £49 5s 0d (site deeds, While Estate Trustees Collection) in order to construct the necessary bridge over the Leven. However, the company had omitted to apply for an amending licence for the tramway, and was duly reprimanded for the fact by Colonel Ford, one of the official government explosives inspectors, who visited the works on 14 October. The inspector also picked up on a number of other faults, including defective lightning conductors to all buildings (HF LW/959/284).

In April 1886, Collinson, at the request of J W Weston, began to examine options for installing hydraulic accumulators at the works. The intention seems to have been to use them to operate the new cartridge press. The initial idea was to take water from a stream which flowed into the headrace above the higher stove house, but the final solution involved tapping the stream issuing out of Bigland Tarn (HF LW/959/314, 315, 317, 318 and 387a). It may partly have been implementation of this scheme which caused the works to be the subject of further visits by government inspectors on 19 May and 21 September 1886: both visits seem to have been necessitated by ongoing building work, particularly in the vicinity of the cartridge house. On the second visit, Colonel Ford again had occasion to reprimand the company for extending a tram line through the blast wall protecting the expense magazine without permission, and ordered them to erect an additional blast bank to shield the press house (HF LW/959/319 and 323). Other alterations and additions to the factory made by the new owners but not recorded in the surviving HF papers can be seen by comparing the 1863 sale plan (Fig 6) with the OS first edition 25-inch map surveyed in 1888 (Ordnance Survey

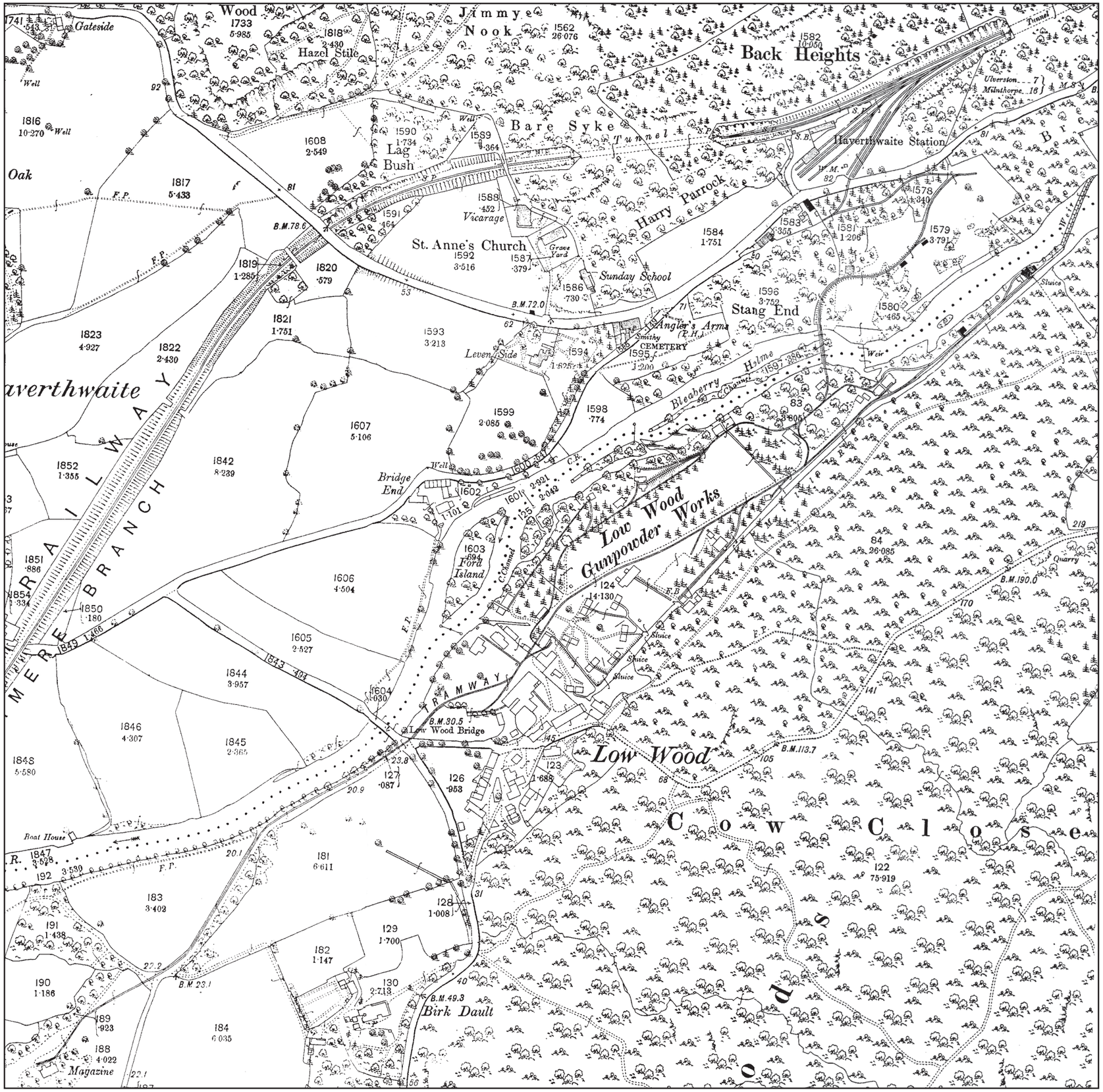


Figure 7. *Lowwood Gunpowder Works as mapped at 1:2500 scale in 1888 ('the OS first edition 25-inch'). (Reproduced at c 1:4000 scale from the 1890 Ordnance Survey map)*

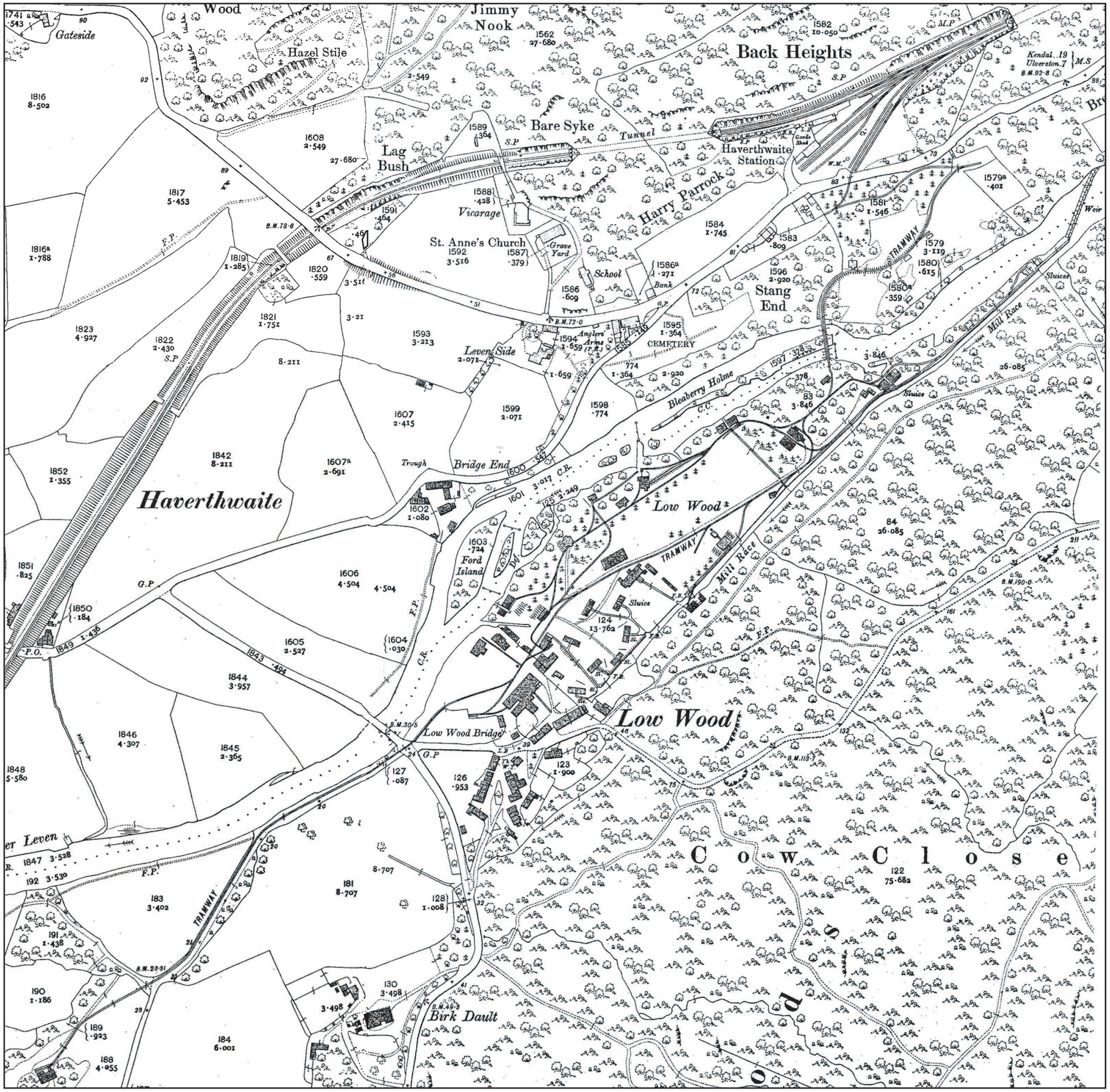


Figure 8. *Lowwood Gunpowder Works as mapped at 1:2500 scale in 1911 ('the OS second edition 25-inch'). (Reproduced at c 1:4000 scale from the 1913 Ordnance Survey map)*

Factory No. 23 Lowe's
Non Y Amending Licence No. 3034. LOWOOD FACTORY. – REFERENCE

NOT ON LICENSED AREA.

2 to 5. COOPERAGES.
6. SAWPIT. 11a. LABORATORY.
7. CYLINDER HOUSE.
8. CHARCOAL STORE.
10a. WEIGH HOUSE.
12. OFFICE.
13. DO.
14. SALTPETRE WAREHOUSE. } NOT IN USE
15. DO. DO. }

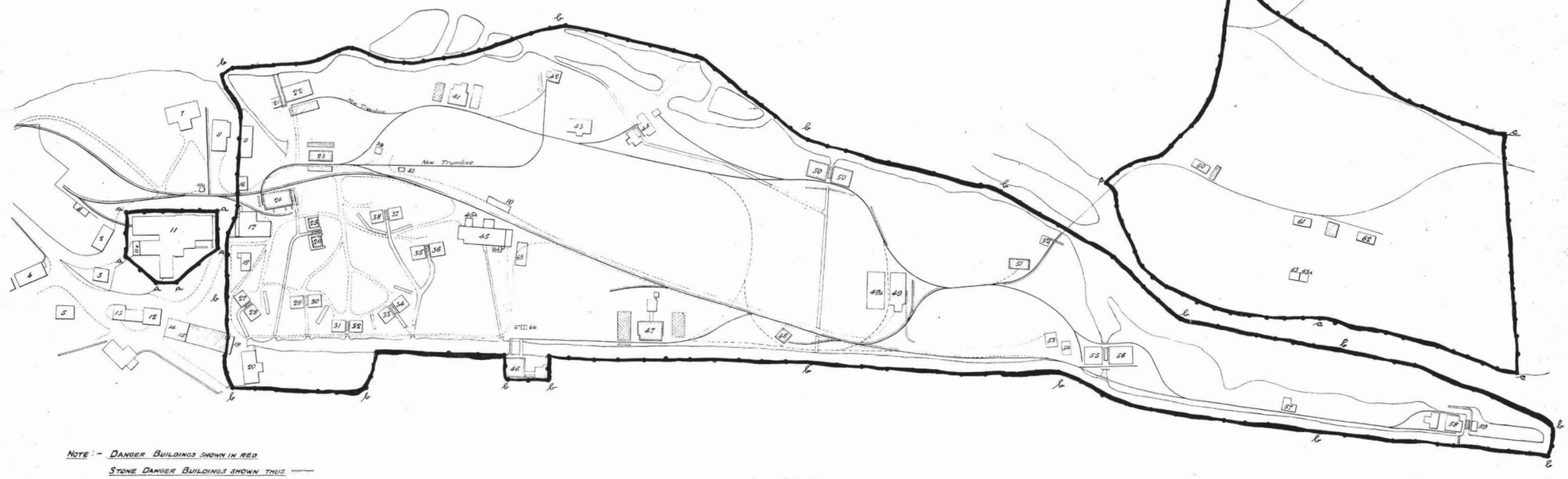
ON LICENSED AREA.

NON DANGER BUILDINGS.

9 10. WOOD SHS.
11. SALTPETRE REFINERY.
16. FIRE ENGINE HOUSE.
17. STORE FOR CASKS ETC.
18. [illegible] HOUSE.
19. CARPENTERS SHED.
20. DO.
21. CARTRIDGE PUMP HOUSE.
39. HARNESS ROOM.
40. LOOSE BOX.
43. STORE.
45. SAW MILL & PUMP.
45A. CARTRIDGE PRESS HOUSE PUMP.
52. BOILER HOUSE (DEMOLISHED).
53. STORE.
54. DO.
59. PUMP HOUSE.
63 66. BOILER HOUSES.
63A. WOMENS DRESSING ROOM.
64. OIL ENGINE HOUSE.
65. TRAVELLING SAW.
67. DRYING SHED FOR TIMBER.
49A. STORAGE AND UNHEADING OF EMPTY BARRELS.

DANGER BUILDINGS.

22. CARTRIDGE PRESS HOUSE.
23. CHARGE HOUSE.
24. COMPOSITION HOUSE.
42. EXPENSE MAGAZINE.
49. HEADING-UP HOUSE.
48. EXPENSE MAGAZINE.
50. REEL & GLAZE HOUSE.
51. PACKING HOUSE OR DIRT CHARGE MIXING HOUSE. } NOT USED
55 56. REEL GLAZE & DUSTING HOUSE.
25 to 38. AMALGANATING MILLS.
41. PRESS HOUSE.
44. CORNING HOUSE.
46. STOVE.
47. DO.
57. PRESS HOUSE OR CARTRIDGE HOUSE.
58. CORNING HOUSE.
60. FACTORY MAGAZINE.
61. CARTRIDGE PACKING ROOM.
62. DO. DO. DO.



NOTE:- DANGER BUILDINGS SHOWN IN RED.
STONE DANGER BUILDINGS SHOWN THUS
NEW TRAMWAY 1883-4.
OLD TRAMWAY (STEEL RAILS PUT DOWN, 1883-4)
" " DISPENSED WITH, 1883-4.

AMENDING LICENSES.
OCTOBER 1881 STONE ERECTION TO No 18. WOODEN ERECTIONS TO No 45
MARCH 27TH 1884. EARTH MOUNDS TO No 47.

SCALE OF CHAINS
SCALE OF FEET

BLOCK PLAN OF LOWWOOD FACTORY.

H.M. Inspector of Explosives
2nd March 1926.

NOBEL INDUSTRIES LIMITED.
TECHNICAL DEPT. — ENGINEERING SECTION
DRAWN BY
TRACED BY 25.4.26
CHECKED BY
PASSED BY
H.O. D 15-142

Figure 9. *Plan of Lowwood Gunpowder Works accompanying Amending Licence no.3034 ('the 1926 factory plan').(ICI plc, copyright reserved)*

1890a, b and c; see Fig 7). This reveals for example that a number of buildings had also been erected at Stang End on the far bank of the river alongside the new tram line to Haverthwaite Station. Further information, most noticeably regarding other re-routings of the tramway system within the factory in 1883-4, is contained on a later map of 1926 (this section below, and Fig 9).

On 6 September 1887, the new owners experienced their first fatal accident when the ignition of an accumulation of gunpowder dust in a pair of incorporating mills undergoing maintenance, fatally burned the two men carrying out the work (Explosives Inspectorate 1887). Tyler (2002, 148) states that electric lighting was introduced to the factory the following year, but correspondence in the HF archive, dated 26 December 1888 (LW/959/346), merely records discussion about the merits and safety of so doing. The implication is that electricity did not come to Lowwood until 1889 at the earliest.

James Collinson died in 1895, and was succeeded as works manager by J H Ellwood, who held the job for the next 31 years (Imperial Chemical Industries 1929, 342). Although the lease on the Lowwood factory was not due to expire until 1899, the Wakefield company negotiated a new lease with the Bigland family on 6 October 1896, to run from 14 February 1897 (site deeds, While Estate Trustees Collection; CRO(B) BDKF/242/1; CRO(K) WD/BGLD/2420). The period of the new lease was 21 years; the rent was set at £629 for the first twelve years, and thereafter at £707 *per annum*. One clause required the lessees to enclose the works within 'a substantial wood or iron fence' if they utilized any land on the east side of the main headrace for manufacturing purposes. Although a map of the works accompanies the lease, it appears to be a re-drawing of the 1863 sale plan rather than a new up-to-date survey. In 1903 Wakefield & Co was re-structured into a limited liability company with capital of £75,000 (Imperial Chemical Industries 1938, 177).

On 12 March 1903, an explosion in the no. 2 press house at Lowwood killed the two men working inside. Although the lightly-constructed building was destroyed, the machinery was not badly damaged. There had been complaints about the state of the press before the accident, but the official investigation found that the most likely cause was the presence of foreign matter in the powder (Explosives Inspectorate 1903).

A month before the accident the company received a quote from the Kendal firm of Wright, Heaps and Westwood regarding a 17bhp (12.7kW) turbine to power the glazing house (HF LW/1901/007 and LW/Misc/038). It is not recorded if the purchase went ahead, although thirty years later a 25bhp (18.6kW) unit was employed at the building (MMB, 19). In 1909 the company ordered a turbine for use in the sawmill from the firm of Gilkes & Co, also based in Kendal. This was a 40bhp (29.8kW) 'Trent' unit, manufacturer's no. 2065 (information from Sharon Bianchi, Gilbert Gilkes & Gordon Ltd); it was delivered and installed early in 1910 at a total cost of £208 18s 6d (CRO(B) BDKF/241/1). The company bought another turbine from the same company almost straightaway, this time to generate electricity (Tyler 2002, 151): this second machine was of the 'Vortex' type, no. 2145, capable of outputting 6bhp or 4.5kW (information from Sharon Bianchi).

In 1911, the factory was re-surveyed by the OS; the result (hereafter called the OS second edition 25-inch map), was published two years later (Ordnance Survey 1913a, b and c) and is reproduced here as Fig 8. The map reveals that a number of new buildings had been erected in the 23 years since the first edition 25-inch was surveyed, despite the fact that surviving company papers make no mention of any of these developments. The major additions seem to be two buildings situated next to the sawmill leat plus several new annexes to the sawmill itself, and another entirely new erection close to what in 1863 (Fig 6) had been the dust house at the centre of the site; changes are also apparent to the layout of the internal tramway system.

In 1916, the Wakefield company renewed its lease on the factory. The indenture is dated 28 November, but the lease actually ran from the February; as before, the term was 21 years, but with the yearly rent now set at £1100 (site deeds, While Estate Trustees Collection). In 1918, Wakefield's merged with other blackpowder manufacturers to form Explosives Trades Ltd, later Nobel Industries Ltd, itself absorbed into ICI in 1926 (Crocker 1988a, 2). At the time of the ICI takeover, J H Ellwood was replaced as works manager by C R Cowtan, formerly manager at the nearby Blackbeck works (Imperial Chemical Industries 1929, 342 and 347; Tyler 2002, 152).

A year later, ICI purchased the leasehold parts of the factory from the Bigland family for £18,000 (site deeds, While Estate Trustees Collection). The conveyance, dated 16 November 1927, is accompanied by a plan of the works, but as this appears simply to be a rehash of the 1863 sale plan, it cannot be used as evidence of the factory layout at this time. Instead, a more accurate plan dating from 1926 survives in the possession of ICI at their Ardeer site in Scotland. This plan (hereafter referred to as the 1926 factory plan), is a copy of that which originally accompanied amending licence no. 3034, and seems, together with the 1933/4 Manufacturing Method Book (MMB) for Lowwood, to be the authority for Ted Patterson's (1995, 15-19) published plan and account of the works. Information on the factory plan not mentioned by Patterson shows that it was marked up on 28 July 1926, and signed off by H S Watts, HM Inspector of Explosives, on 6 November. It is reproduced here as Fig 9. It is important not just because it records the layout of the factory at a given point in time (and in the case of the tramway and selected features, alterations made between 1881 and 1884), but because it gives the function of each building. In addition, all buildings are identified by a single sequence of numbers. This particular sequence seems to have been initiated between 1863 and 1866 (compare HF LW/1863/005 with LW/958/267 and 571) and to have remained in use for around 70 years, being expanded as necessary, until finally replaced by a completely new sequence a few years prior to 1933, probably *c* 1928/9.

In 1928, ICI embarked on a major programme of modernisation of the works (Imperial Chemical Industries 1929, 342). Only one of the existing seven pairs of stone edge-runner incorporating mills was retained, five of the others being converted to single suspended-runner mill operation, and the remaining pair scrapped altogether. The new incorporating machinery was made by Dryden's of Preston, but reportedly arrived at Lowwood second-hand via the Fernilee Powder Mills in Derbyshire (Patterson 1995, 16; Tyler 2002, 152). In the same year ICI purchased a 13½-inch (342.9mm) type CA 'River' turbine from the firm of

J J Armfield based at Ringwood in Hampshire (HRO, 38M 90/D2), although it is not recorded what it was intended to power. New glazing drums were also introduced around this time, obviating the need for stoving of loose powder (Tyler 2002, 152). In 1931-2 the existing reels at the reel and glaze house were reconstructed and new ones installed (possibly replacing existing glazing barrels). In 1933/4, the press at one of the two press houses was said to be 'new', while the old Hastie machine in the main corning house, installed as far back as 1869-70 (this section above), had at some point been replaced by one of the 'Nobel type'. By this date, the one remaining stove house was also heated by a small steam turbine direct-coupled to a fan (MMB, 35; Patterson 1995, 16-18; Tyler 2002, 153). New recreation and mess rooms, and upgraded washing and changing facilities, had also been provided at the works by 1929 (Imperial Chemical Industries 1929, 342). Despite all this investment, falling demand for blackpowder caused ICI to close the works only a few years later in order to concentrate production at fewer sites, and Lowwood ceased production in May 1935. The suspended-runner incorporating machinery was dismantled and transported to Ardeer in Scotland for reuse there (Patterson 1995, 16 and 44), and on 1 October the main factory freehold was sold to Augustus While for £1720 (site deeds, While Estate Trustees Collection).

In 1938 the disused factory was resurveyed by the OS. However, due to wartime economies only the northernmost of the three sheets covering the works was ever published (Ordnance Survey 1940), while the plates for the unpublished maps were subsequently destroyed by enemy bombing. Unfortunately, therefore, mapping which has the potential to chart post-1926 building development at the works is not available to the historian.

5. THE PROCESS OF GUNPOWDER MANUFACTURE

The method of gunpowder manufacture has been described in detail elsewhere (*eg* Cocroft 2000; Crocker 1999; Patterson 1995) and only a brief outline will be given here in order to provide the reader with a general background to the processes described in section 6.2 below. Details of the precise method followed at Lowwood in its final years are known from the factory Manufacturing Method Book (MMB), a copy of which survives in the Patterson Collection in the NMRC in Swindon. Internal evidence shows that this document was current in 1933/4. Limited details on the specifics of processes used at earlier times survive in a variety of other sources. Some of the terminology appears to be Lake District vernacular; where this is the case other commonly used terms are given in parentheses. Stages of manufacture also varied slightly according to the type and intended use of the powder.

The three ingredients of gunpowder are saltpetre, charcoal and sulphur in the approximate ratio 75:15:10, although the precise mix varied according to the quality of powder desired: in 1933/4 some Lowwood blasting powders, for example, contained only 62.5-67 per cent saltpetre and as much as 22.5 per cent charcoal (MMB, 4). These constituents do not react chemically, but are simply blended together. The manufacturing process was therefore designed to create a thoroughly combined mixture of the correct density, in an evenly-granulated form. Saltpetre has two chemical forms: potassium nitrate (nitrate of potash) and sodium nitrate (nitrate of soda). The former is stable under ordinary climatic conditions and was always the saltpetre of choice. Sodium nitrate absorbs water from the air, but was less expensive; it was normally used for the cheaper blasting powders, but had to be kept dry or it lost its efficacy. Blackpowder made from the two forms was distinguished as N/P or N/S powder (Patterson 1995, 10-11). By 1933/4, Lowwood produced only N/P powders, although it did undertake the pressing of N/S blasting cartridges on behalf of its sister New Sedgwick works since it was the only factory in the ICI North of England Gunpowder Group which possessed a particular size of cartridge mould (MMB, 42).

The first stage of manufacture was the preparation of the three raw ingredients. **Saltpetre**, imported from abroad in its 'grough' or raw state, needed to be refined. The normal method of achieving this at Lowwood was by a cycle of cold washes followed by gentle boiling and re-crystallisation, which produced fine crystals of almost pure saltpetre, but by 1933/4 the MMB (page 3) makes clear that the works was receiving supplies of pre-refined potassium nitrate from the New Sedgwick factory instead. Imported **sulphur** could also contain impurities, but again by 1933/4 the MMB (page 1) implies that it was arriving at Lowwood already in a pure state. Prior to this date, refining of both saltpetre and sulphur (if necessary) would have been undertaken at the **refinery**. For a couple of years immediately after Lowwood's foundation in 1799, **charcoal** was bought from local suppliers, but in 1801 until probably the early 20th century, charcoal was made on site in sealed **retorts**; by 1926 the available evidence indicates that reliance had moved back to external sources. At gunpowder works, these ingredients were normally kept in separate stores, known appropriately as the **saltpetre store**, **sulphur store**, and **charcoal store**. However, it is only at certain times that there is specific evidence for separate, dedicated saltpetre and sulphur stores at

Lowwood; at other times these materials are most likely to have been stored within the refinery.

In the **preparing house** (mixing house) the charcoal and sulphur were ground to a fine powder in an edge-runner mill. All the ingredients were sieved to remove lumps or grit before being weighed out in the correct proportions sufficient to produce a single 'charge' (anything between 40 and 80lb (18.16-36.32kg) depending on the legislation in force at the time), and mixed in a drum containing rotating arms. At Lowwood, grinding and mixing seem always to have been water-powered. Each mixed charge, called a green charge, was transferred to the **charge house** for temporary storage before transfer to the **amalgamating** or **incorporating mills**.

In the **incorporating mills** individual green charges were fed into edge-runner mills that mixed and compacted each one into a denser mass known as **mill cake** or **ripe charge**. At Lowwood in the 19th century charges were often milled for 2-3 hours, but after *c* 1873 the time was reduced to around 1 hour 30 minutes. During incorporation the process was supervised from the comparative safety of the **watch house**, and the charge periodically dampened to help it meld together. All seven pairs of incorporating mills at Lowwood were powered by waterwheels, and until 1928 the milling machinery within was over-driven (*ie* driven from above); in 1928 five of the pairs were reduced to single mills employing under-driven machinery (*ie* driven from beneath the bedplate). Once incorporated, ripe charges were removed and stored until the next stage of manufacture. Some works had a dedicated **ripe-charge house**, but at Lowwood the building performing this function seems to have been referred to more frequently simply as an **expense magazine**. Expense magazines were buildings where powder was stored between the various stages of manufacture. They were a legal requirement at all gunpowder works because a series of Acts of Parliament passed between 1772 and 1875 placed strict limits on the quantities of powder which could be present in process buildings at any one time.

After incorporation, the powder had to be compressed at the **press house** in order to turn mill cake into slabs of high density called **press cake**. The MMB (pages 8-10) provides an exact account of this process at Lowwood as performed in 1933/4; details would have varied slightly over time, but the description is no doubt valid in its essentials for earlier periods too. First the mill cake was broken down by hand using wooden bats, and mixed with dust returned from the corning house. A Muntz-metal plate was then placed on to a flat bogie (truck), a wooden frame placed round it, and the powder spread thinly across the plate; another plate was placed over the first and the process repeated until a large 'sandwich' 29 layers high had been created within the frame. The bogie with its load was then pushed onto the press table and the ram activated. A second bogie was loaded while the first was under the ram. It is possible that the early presses at Lowwood may have been screwed down by hand, but certainly by 1859 the factory was using hydraulic pressure generated by water-powered pumps. These pumps were located in separate **pump houses**.

By this stage the powder had reached a satisfactory mix and density. It now needed to be turned into rounded and evenly-sized grains. The first part of this process was carried out in

the **corning** or **granulating house**, which reduced the press cake to angular grains of approximately the correct size. When Lowwood opened, powder would have been corned by placing the press cake in a series of oscillating sieves alongside blocks of *lignum vitae*, but by 1859 these crude shaking-frame machines had been replaced by safer designs which used a combination of toothed and smooth rollers to granulate the press cake. The grains were then shaken through a stack of sieves of different meshes in order to separate out grains of the required size from those too big (stops) or too small (dust); stops went back through the rollers a second time. The available evidence suggests that corning machines at Lowwood were always powered by waterwheels.

From the corning house, the angular grains went to the **glazing house** where they were tumbled in wooden barrels for a number of hours in order to smooth them, with graphite added for part of the time. The frictional energy of the grains helped to dry the powder; but the process also rendered the grains less hygroscopic (prone to absorb water) and increased their density, as well as smoothing them thereby helping the powder to keep its structure. The amount of graphite added depended on the 'brightness' required. Some powders requiring an extra 'polish' were subsequently put into **reels** – similar to glazing barrels but with the sides formed of a particular type of linen called 'Irish Crash' (MMB, 19-29). Lowwood probably did not reel any of its powder before 1861, when a **reel and glaze house** was constructed. At Lowwood glazing and reeling seem always to have been water-powered – most of the time by waterwheels, but from 1903 the glazing house (but not the reel and glaze house) was powered by a water turbine.

Before 1882, all glazed powder went straight to the **stoves** to remove residual moisture. In that year, however, Lowwood started selling powder pre-formed into blasting cartridges as well as loose in barrels, and powder destined for cartridge manufacture travelled first to the **heading-up** and **cartridge houses** (this chapter, below). Lowwood's stoves seem always to have been heated by steam or hot air ducted in pipes around the floor; the steam/hot air was produced in **boiler houses** detached from the **stove house** (drying house) itself to reduce the risk of sparks igniting the powder. In 1928 new glazing barrels were installed capable of removing more of the moisture content, and after this date only blasting cartridges were stoved, not loose powder. In 1933/4 the MMB (pages 35-6) states that cartridges were stoved at 150^{o} F (65.5^{o} C) for a day (6-8 hours) and then left under residual heat overnight as the stove house cooled down. Details of the earlier stoving régime for loose powder are not recorded.

After stoving, loose powder went to the **dust house** for removal of fine dust and final sizing of the grains. Before 1880, dedicated dust houses are recorded. By 1880, dusting was reportedly carried out in the same building as reeling and glazing. In 1933/4, the dusting machinery comprised a slope or dusting reel – an inclined, rotating 'mesh' barrel – and a sizing machine (separator) - a nest of three sieves of different mesh sizes. Dust was removed from the powder by the slope reel, while the nest was agitated by cranks, and over-sized grains retained by the first sieve. The dust and over-sized grains (locally called 'pin dust' and 'chubbins') were returned to the charge house and incorporating mills to start the manufacturing process again (MMB, 24-8). All this machinery was powered by a waterwheel.

The machinery in the earlier, dedicated, houses would no doubt have been comparable to that recorded by the MMB in 1933/4, but the likelihood is that it was operated by hand crank.

After dusting, loose powder went to the **heading-up** or **packing house** to be weighed and packed into barrels ('heading up' refers to the closing of the barrel). Finally it was transferred to the **factory** or **store magazine** to await despatch to customers.

From 1882, powder destined for cartridge manufacture followed a different route through the factory. After the glazing house it went first to the heading-up house to be weighed, and then to the **cartridge house**. Here the powder was poured into moulds and compressed under high pressure into solid pellets with a central hole to take a fuse. As with the powder presses, these cartridge presses were hydraulically powered; however, unlike the former, the Lowwood cartridge presses were driven by pumps powered by hydraulic accumulators, not waterwheels. Once formed, the cartridges were dried in the **stove house** (this chapter above) before being individually wrapped and packed into boxes in the **cartridge-packing house**. As with other gunpowder works, cartridge packing seems to have been carried out mostly by women. Boxed cartridges were kept in the **factory** or **store magazine** until despatch.

Each batch of powder was checked for quality and reliability. This was done by test firings on the **proofing range**, or by less spectacular means in the **laboratory**. By 1863, the Lowwood range was situated in the largely open area at the centre of the works; it may have been disused by the 20th century. There is some evidence to suggest that in the early years of the 19th century the range was located further to the south.

Other buildings known to have existed at Lowwood include a **sawmill**, **cooperages**, **carpenters' shops**, **cart house**, **loose box**, **harness room**, **fire-engine house**, **office**, **weighbridges**, **privies**, and miscellaneous **stores**. Horses were needed to pull carts, and after 1869 also to propel bogies (trucks) around the tramway system within the works; the function of the other buildings listed is otherwise fairly self-explanatory. At Lowwood, **changing** – the donning of special clothing by the workforce before commencing their daily tasks - was carried out at the watch house. Female workers, however, had their own **women's dressing-room**. **Searching –** checking the workers to ensure they carried no matches or other incendiary devices – was carried out in the watch house and the women's dressing-room.

6. FEATURE CATALOGUE AND DESCRIPTION

The following catalogue of features is divided into three sections: the first and last (sections 6.1 and 6.3) deal with features which pre- and post-date the gunpowder works; the central, much longer and more detailed, part (section 6.2) describes structures which make up the gunpowder works itself. The overall EH plan (Fig 142) which shows both surviving structures and modern detail, is reproduced here at a scale of 1:1000, although the site was mapped at a variety of scales in the field.

The first and third sections are broken down into sub-sections ordered by phase. However, section 6.2 describing the gunpowder works is arranged by process rather than date order, with sub-sections detailing each building and structure according to function. This creates problems, for inevitably many buildings changed function over time. Where this is the case, cross-references will guide the reader to other relevant sections of the catalogue. Section 6.2.1 summarises evidence for how the factory was powered, whilst section 6.2.2 discusses structures related to the preparation and storage of raw materials used to manufacture gunpowder (in the main, charcoal, sulphur and saltpetre); section 6.2.3 follows the steps in gunpowder production from grinding and mixing of ingredients through to the packing and storing of the finished product, while section 6.2.4 deals with buildings specific to cartridge manufacture (a process only introduced to Lowwood in 1882); section 6.2.5 covers evidence for the testing of gunpowder. Ancillary buildings are detailed in section 6.2.6, and buildings of uncertain purpose in section 6.2.7. The next two sections deal with different aspects of transport: section 6.2.8 with the movement of goods to and from the works, section 6.2.9 with how powder was transported between process buildings during manufacture. Section 6.2.10 forms a catch-all for a miscellany of other features at the works; a final section, 6.2.11, describes the workers' houses in Low Wood hamlet, and the manager's residence, Birk Dault.

Every gunpowder structure for which there is cartographic, documentary or physical evidence is included in the catalogue; buildings for which there is cartographic or physical evidence (*ie* those for which there is precise locational information) have also been allocated a unique number. With two exceptions, the numbering scheme adopted follows and builds on the sequence recorded on the 1926 factory plan (Fig 9), and need bear no relation to the order in which buildings were constructed or how the site developed over time; indeed, numbers on other plans and those referred to, for example, in sources such as the MMB (which in its surviving form dates to 1933/4), show that alternative sequences were in use at other times. Where correlations are possible between the various numbering systems, these are highlighted in the text.

Numbered buildings will all be found on a series of phase diagrams (Figs 130-41) reproduced in chapter 7 of this report, which attempts a chronological overview of the site's development combining the documentary, archaeological and architectural evidence detailed in chapters 4 and 6. The following text should be read in conjunction with those diagrams.

6.1 Phase 1. Structures Pre-dating the Gunpowder Works (Figs 130-1)

6.1.1 Weir

The 1796-9 Bigland estate map (Fig 3) depicts an unnamed weir across the River Leven about midway between Ford Island and Bleaberry Holme. As the map does not show it associated with any feature which can be interpreted as a leat channel, it is highly likely that it was already disused by that time. It was not maintained by the gunpowder company after 1799, for although it was still extant in 1846 it is not shown on any map or plan after that date (compare Figs 4 with Figs 6-9).

Cartographic evidence suggests that much of the weir had already disappeared - presumably washed away by the river - before the end of the 19th century, therefore, but a *c* 23m length is still preserved to its full original height adjacent to the left bank where protected from the full force of the Leven by gravel banks upstream; an additional few metres of the rear basal courses are also visible in the bed of the river beyond the upstanding section. The weir is stone-built, 4m wide at its base, and roughly triangular in section comprising a near-vertical wall facing downstream backed by a 'wedge' of masonry upstream; the front face is constructed of roughly-coursed rubble flagstones, bedded on a natural rock outcrop and topped by a single course of flagstones set vertically (Fig 10), while the upstream side is formed from the same rubble flagstones laid horizontally, edge-on to the river, but dipping in cross-section at a *c* 45° angle in relation to the front vertical wall face to create a battered surface (Fig 142). Its elevation is *c* 7.3m AOD, or some 1.6m above normal (modern) water level.

Fig 10. The front face of the unnamed, early weir between Ford Island and Bleaberry Holme. The outline of the lower corning house mark IV is just visible behind. (NMR: DP003526)

6.1.2 Lowwood Ironworks

The documentary history of the Lowwood ironworks has already been outlined in section 4.1 above, and, where it impacts on that of the gunpowder works, in section 4.2 also. However, in brief, a charcoal-fired blast furnace plus facilities for boring and/or polishing iron were erected at Low Wood in 1747, with the latter side of the business soon replaced by a forge. Both enterprises were shut down in 1785, but the infrastructure was abandoned rather than demolished, and in 1799 the gunpowder company which took over the lease adapted the disused furnace complex for reuse as a saltpetre refinery (the lease expressly forbade the complex's demolition unless replaced by buildings of greater value); as a result, parts of the complex most probably survived largely unaltered until 1849 when it was substantially rebuilt to provide a new, purpose-built, refinery erected to much the same footprint. The 1799 lease also names a number of other structures standing when the gunpowder company took over, namely: a 'large coalhouse' (*ie* charcoal barn - implying the

existence of one other, smaller, charcoal barn on the site) and unspecified warehouses. The 1796-9 Bigland estate map (Fig 3) portrays the layout of the ironworks at the very end of its life, and shows five buildings in addition to the blast furnace itself. Of these, four were retained by the gunpowder company and adapted to new use, although the fifth had disappeared by 1846 (compare Fig 4): it was probably demolished as early as 1799 to make way for the first incorporating mill. The map evidently also shows the ironworks powered by a headrace along the eastern edge of the site; this race seemingly supplied both furnace and forge.

Of the four buildings (excluding the blast furnace) retained by the gunpowder company, two survive intact to the present day, and although now much altered and converted to domestic use still preserve sufficient evidence to show that they originally functioned as a charcoal barn and iron-ore store (the former is without doubt the large charcoal barn mentioned in the 1799 lease). The other two buildings also survive, albeit in a ruinous condition; their function is less certain, but they are here interpreted as the 'small' charcoal barn - whose existence is implied by the 1799 lease - and possibly a stable and/or cart house. The function of the fifth, demolished, building cannot be determined solely from cartographic evidence, but is likely to have been the forge. The 'small' charcoal barn and possible stable and cart house appear on the 1926 factory plan (Fig 9) as buildings 17 and 20, which are therefore the numbers used for all phases of both structures in the current report. However, parts of the 'large' charcoal barn and ore store were disused in 1926; in consequence only elements are numbered on that plan, with each element treated as a discrete building (buildings 14/15 and 12/13 respectively). For present purposes, therefore, new numbers (102 and 101) will be allocated to the entirety of each structure, with the various compartments into which they were subsequently divided identified by a letter suffix: thus buildings 14/15 will here be numbered 102a, buildings 12/13, 101c and 101a. The demolished blast furnace and forge buildings, which do not feature on the 1926 factory plan, will be given the numbers 100 and 103.

Weirs and Leats

As previously argued (section 4.2 above), the ironworks headrace was controlled by a weir at Stang End, evidently located on or very close to the sharp westward bend in the Leven (compare Fig 3). This would seem to be an ideal position for such a structure, for it would mean the intake for the headrace was located on the outside of a bend where the current is fastest and silting presumably less of a problem. However, the area has been much altered since 1799: first by the gunpowder company's extension of the headrace, second by the construction of the reel and glaze house *c* 1861 (section 6.2.3 below), and finally in the 1960s by the dumping of rubble in connection with the heightening and strengthening of the side of the headrace in its reuse for the generation of hydro-electricity (section 6.3.2 below). In consequence, no definite trace of Stang End weir or the abandoned upper course of the ironworks headrace was found during the course of EH's investigation. However, the absence of evidence for bolt holes in the riverbed with which to anchor timberwork, together with the fact that the two extant weirs upstream and downstream (sections 6.1.1 above and 6.2.1 below) are both stone-built, would tend to point to the likelihood of the Stang End weir having been of stone, rather than wood, also. If so, suggestions of a thin band of flagstones set on

edge which are visible, when water levels are low, along the eastern edge of a small inlet immediately north of the site of the reel and glaze house, may be part of it; further traces may be preserved beneath the gravel banks on either side of the river.

Although the headrace's final route to the furnace is not shown by the 1796-9 Bigland estate map (Fig 3), field evidence shows it took the form of a covered leat with the race disappearing into a stone-arched culvert near the stable/cart house (Fig 11), and re-joining the present tailrace close to where the latter discharges into the Leven (Fig 12). The present investigation has not traced the culvert's course underground between these two points, but it must pass beneath what is now the Clocktower complex in order for power to have been delivered to the bellows at the blast-furnace. The most likely course of the race is discussed as part of the description of the blast furnace below (this section).

Fig 11. The entrance to the covered section of the ironworks headrace leading to the blast furnace. (Christopher Dunn, July 2005)

Fig 12. The outfall of the covered section of the ironworks headrace (shown in detail at inset) back into the main tailrace. The modern hydro-electricity station is visible at left of frame. (Christopher Dunn, July 2005)

The present report has also argued that the headrace supplied the forge in addition to the blast furnace; it must therefore have bifurcated before the covered section, with a subsidiary leat running off to the latter building (section 4.2 above). Again, the Bigland estate map does not show any such feature (presumably because the leat was disused, even silted up), but if the position of the forge has been correctly identified (this section above), the most obvious course for the presumed leat is that which later maps of the gunpowder works (Figs 4 and 6-9) record took water to incorporating mills 25/26 and the preparing house. In short, it is probable that the gunpowder company did not construct the latter leat from scratch, but adapted an existing feature inherited from the ironworks.

There is no field evidence, however, on which to test any of the hypotheses presented above. If, as seems likely, the gunpowder company widened the ironworks headrace, then little or nothing of the original race is likely to survive. Documentary evidence also indicates that at the very least the presumed branch leat to the forge was also re-puddled - and

therefore relined - in 1799 (section 4.2 above), obscuring evidence which might prove if that feature, too, had earlier origins; any evidence to that effect has since been further masked by the feature's burial beneath/replacement by the modern headrace to the hydro-electricity station.

Blast Furnace (building 100)

The site and overall shape of the Lowwood blast furnace, built in 1747, is known from the 1796-9 Bigland estate map (Fig 3), which seems to depict the site just before it was assigned to the Lowwood Gunpowder Company in 1799. It is one of a group of eight charcoal-fired blast furnaces established in Furness (now south Cumbria) and north Lancashire during the first half of the 18th century, and like these others would have consisted of a square furnace stack abutted by a number of building ranges. The principal ranges were a blowing house containing bellows powered by an adjacent waterwheel, a bridge house often incorporating the charging house in which the different elements of the charge – charcoal, iron ore and any flux – were gathered and cast into the furnace in appropriate quantities, and a casting house in which the molten slag and iron were periodically drawn off, the latter into channels in the floor to form pig iron. There were often further buildings and rooms, including bothies, stores and offices. The individual parts were combined in different ways, according to the particular topographical influences of a site (see Bowden 2000, 51-8, figs 3.6, 3.7, 3.9, 3.11, 3.15 and 3.17).

The 1796-9 map shows the Lowwood blast furnace as a large T-shaped building. Part of the ground-floor walling of the narrow south-east wing still survives in a ruinous condition, and is the key to interpreting the arrangement of the overall complex, although very little, if any, of the remainder of the structure seems to have survived conversion into a saltpetre refinery in 1799, which was itself largely rebuilt in 1849 (section 4.2 above). This narrow wing, shown roofed on all maps of the site from 1796-9 to 1926 (Figs 3, 4 and 6-9), must have formed the bridge house with a charging house occupying the now missing first floor (identified as building 100a on Fig 131). The wing was finally pulled down in 1928 (Imperial Chemical Industries 1929, 340), but the demolition was evidently incomplete. It is sited to receive ore and charcoal from the iron-ore store and 'large' charcoal barn (this section below) - which survive in adapted form on the slope above it (Fig 13) - and enable them to be transported easily to the top of the furnace stack. The positions of these stores in relation to the charging house is very reminiscent of analagous structures at Backbarrow, Duddon, Nibthwaite and Newland Furnaces (Bowden 2000, figs 3.6-3.13, 3.17 and 3.19).

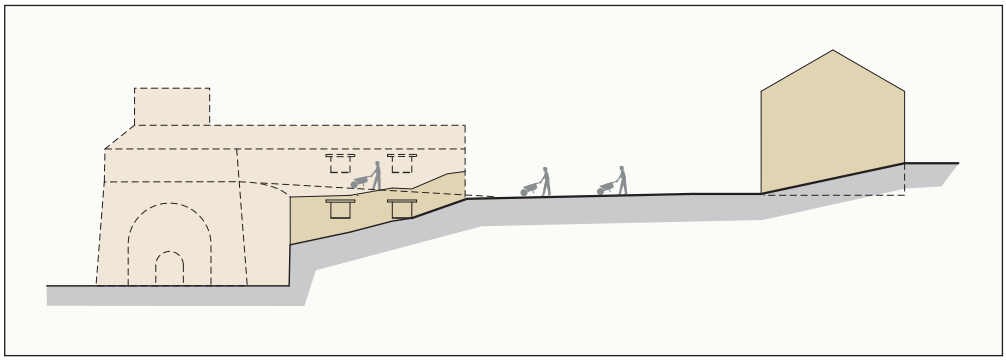


Fig 13. EH cross section of the blast furnace and adjacent buildings, showing the relative positions of the furnace stack and bridge house to the iron-ore store upslope.

All that remains of the Lowwood bridge house is the south-west side wall almost to first-floor level, and the return of the south-east end wall (Figs 14 and 27), although the continuation of the wall-line is marked on the ground by a steep scarp (Fig 142). Two partly-blocked window openings survive in the side wall, both with *in-situ* external slate cills and wooden lintels (Fig 15); they lit what may have been a small bothy sited below the charging house, similar to the arrangement which existed at Duddon, although if so the floor of the bothy now lies buried beneath earth brought in to raise the ground level and create the modern garden which now occupies the interior of the building. The north-west end of the side wall ends with a straight joint; no archstones are visible, but the existence of the straight joint suggests that, again as at Duddon, the bridge house originally abutted the outside of the stack with a quadrant arch, partly for insulation and partly to help buttress the stack (Bowden 2000, 49 figure 3.7, and 53-4). The furnace stack itself would have been a massive, square stone structure with battered outer walls around its charging shaft, and must have stood at the north-west end of the charging house (identified as building 100d on Fig 131), immediately south-west of the position now occupied by the clock tower of 1849. The topography of the Lowwood site, combined with the shape of the building on the 1796-9 map, suggests that water for the waterwheel was fed past the north-east side of the stack, implying that the blowing house lay on its north-west side (building 100b on Fig 131). The range shown on the south-west side of the stack must therefore have contained the casting house (building 100c on Fig 131). The size of the blast furnace complex depicted on the 1796-9 map, however, seems greater than can be accounted for by the existence of just the stack and these three buildings, suggesting it housed additional functions.

Fig 14. The interior of the ironworks bridge house viewed from the east. (Christopher Dunn, July 2005)

Fig 15. Exterior face of the surviving side wall of the ironworks bridge house viewed from the west. (Christopher Dunn, July 2005)

According to the 1846 plan (Fig 4), the blast furnace was converted into a saltpetre refinery in 1799, although the similarity of the complex's shape in 1846 to that on the 1796-9 estate map, suggests that much of the shell of the furnace was retained. It is likely, however, that the individual parts were subjected to considerable adaptation, demolition and rebuilding to make them suitable for their new function: the range which included the casting house, for example, seems to have been rebuilt as two separate, single-storey wings or sheds. The massive furnace stack, in particular, would have been an impediment to the convenient use of the existing building complex, as would the waterwheel-pit. At the nearby Nibthwaite Furnace, the lower part of the stack was retained after the ironworks closed (Bowden 2000, 55-6, Fig 3.15) but that is because the site subsequently became a bobbin mill with a new structure at first-floor level only. At Lowwood saltpetre refining was undertaken in buildings at ground-floor level, and it is here that the mass of the furnace stack would have been such an obstruction to easy working that it is probable that it was demolished notwithstanding the stipulation in the gunpowder company's lease that the furnace could be pulled down only if it were replaced by more valuable buildings (section 4.2 above).

The northern half of the blast furnace/saltpetre refinery was rebuilt in 1849, together with the adjacent parts of the two southern wings. The remainder of both wings is likely to retain masonry and openings which relate to the ironworks, but it is impossible to be certain how much or which these are; both wings are described in more detail in the discussion of the saltpetre refinery below (section 6.2.2).

Iron-ore Store (building 101)

The identification of the Lowwood iron-ore store comes not from documentary or cartographic sources, but from its position in relation to the former blast furnace, and from the red staining which the iron ore has imparted to some of the internal walls and floors and also to the soil around the building. An iron-ore store was fundamental to the functioning of a blast furnace, and the Lowwood example was erected in the usual position for such a building, namely uphill from the furnace it served and terraced into the slope to enable iron ore – a heavy and dirty raw material used in considerable quantity – to be unloaded into it from the upper level and drawn out from the lower one. (For iron-ore stores on other Cumbrian blast furnace sites, see Bowden 2000, 59-60, figs 3.21-24). The Lowwood Gunpowder Company partly reconstructed the building as offices in the 19th century (described in section 6.2.6 below), and after the closure of the gunpowder works the building was converted into housing. Although those parts converted into offices are numbered as buildings 12 and 13 on the 1926 factory plan (Fig 9), the whole structure is here numbered 101 for reasons given earlier (this section above).

The 1796-9 Bigland estate map (Fig 3) shows the iron-ore store, without identification, as a long, but comparatively narrow, rectangular building. Although both ends were rebuilt as offices by the gunpowder company, much can be said about the form of the original store on the basis of similar buildings on other sites, and of what survives here. The Lowwood store was terraced into the slope of the land (Fig 13). The interior, which would have had had no intermediate floor and have been open to the roof, was divided into a series of six, narrow, full-height compartments (here numbered 1-6 from north-east to south-west), separated

from each other by stone dividing walls. A number of iron-ore stores on other blast furnace sites in the area, namely at Leighton, Newland and Backbarrow, had divided interiors, one purpose of such an arrangement being to keep different ores separate so that they could be mixed in appropriate proportions when being prepared for a charge (Bowden 2000, 59-60). None of the upper openings through which ore was pitched in can be identified at Lowwood since this part of the structure was later extensively rebuilt.

The lower parts of five of the six compartments in the Lowwood ore store survive: nos. 1 and 2 under the two-bay offices at its north-east end, nos. 3, 4 and 5 (the last one curtailed) under the narrow, lower, central part of the building. Compartment 6, however, was destroyed when the south-west office building was constructed. Compartments 1 and 2 were successively altered when this end of the ore store was converted into offices over basements: both bays were extended out on the downhill side (their original downhill walls being demolished), but on the uphill side only the wall of the first bay was rebuilt, slightly in

Fig 16.
The iron-ore store from the north-east. (NMR DP006441)

advance of the original wall. That this was so is clear from the evidence of the north-east gable wall (Fig 16), which retains much of the poor quality, heavily-mortared slate rubble of the original gable wall of the iron-ore store, which stands out from the better quality rubble of the office extension. The east corner of the ore store survives as a straight joint where the later masonry of the uphill wall abuts it, but there is no equivalent straight joint for the other corner since the later masonry courses in with the earlier. The original gable does not survive to its full height: the base of its uphill slope can be identified, cut by a course of projecting stones laid as a bed for the wider, rebuilt gable above. Inside, the walls dividing the compartments from each other survive as room divisions, but bays 1 and 2 are both single, undivided rooms – the original downhill walls of the ore store were taken down when it was extended. Only the basement of bay 1 was inspected: its whitewashed walls and concrete floor obscure any evidence of former reddening from the iron ore once stored here. The three other surviving compartments (nos. 3-5) are slightly more complete since they

have not been extended, although only their lower (now basement) levels survive, their upper parts having been taken down and rebuilt on their conversion in the 20th century into houses entered from the uphill side of the building. The three compartments all have red staining on their rock floors and rubble walls: the only wall without such staining is the south-west side wall of compartment 5, which is part of the office rebuild. Each compartment is unlit at basement level, is entered through a doorway set to one side with a harr-hung door hinged on iron pivots top and bottom, and has an internal depth of 4.96m and a front wall 0.7m thick. Compartments 3 to 5 are 3.86m, 2.71m and 2.61m wide, the last one curtailed when the office was built at that end. The dividing walls between the compartments are 0.44m thick.

'Large' Charcoal Barn (building 102)

The present report has argued (this section above) that the ironworks had two charcoal barns, here termed 'large' and 'small'. The former can be identified as the large, unnamed rectangular building which the 1796-9 Bigland estate map (Fig 3) portrays almost due west of the blast furnace. The identification is possible because of its position and because, although now heavily altered, it still survives and can be compared to charcoal barns on other blast furnace sites (Bowden 2000, 60-4, figs 3.25-8). Like the iron-ore store (this section above), it is sited close to but uphill from the blast furnace to enable the charcoal within it to be transferred with ease to the charging house and thence into the furnace stack. It was used for a variety of other purposes when the site became a gunpowder works (saltpetre stores, stable and cow house, sections 6.2.2, 6.2.8 and 6.2.10 below), and after that closed was converted into houses.

The large charcoal barn is aligned and gabled to the north-east and south-west, and is built of roughly coursed slate rubble with generally coursed-in quoins. It is 8.94m wide externally, and its gable walls have distinctive courses of multiple through stones. The slate roof was renewed when it was converted into houses, and the purlins in the gable end walls indicate that the roof was also renewed at this time. The barn is terraced into the slope to enable

Fig 17.
View south-west from the modern site entrance towards Low Wood hamlet in 1957. Part of the 'large' charcoal barn before its conversion into residential housing is visible at left of frame. (Ron Mein Collection, copyright reserved)

sacks of charcoal to be delivered into it through taking-in doors in the rear, uphill elevation as well as through openings in the front elevation. A photograph of it taken in 1957 (Fig 17) before its conversion into houses, shows part of its downhill elevation with just a few small openings in the upper levels of the wall. There are now so many doors, garage doors and windows in the front and rear elevations that it is impossible to know what might be old. The downhill wall has a slight change of angle south of centre, and it is possible that it was built in two stages. Whether this is so or not, the interior would originally have been open to the roof, with timber storage racks for the sacks of charcoal.

'Small' Charcoal Barn (building 17)

The 1796-9 Bigland estate map (Fig 3) depicts an L-shaped building immediately north-east of the blast furnace. Its use at this time is undocumented, but it has been argued (this section above) that it should be identified as the second, smaller, charcoal barn within the ironworks, the existence of which can be inferred from the 1799 gunpowder lease. Certainly the building was later used in this capacity by the gunpowder company, for on the 1863 sale plan (Fig 6) it is annotated as 'Charcoal [Store]'. For its subsequent history and uses, see cylinder houses, charcoal stores and coppice barns in section 6.2.2 below.

The rear wing of the building was demolished in the 1960s and buried beneath the massive embankment retaining the rebuilt leat to the modern hydro-electricity station. Only the front (south-west) and north-east gable walls of the more southerly range of the building are still visible, although the latter is mostly embedded within the embankment. Both walls are 0.7m thick, and built of coursed slate rubble with coursed-in quoins. When surveyed in 2004, the walls and land immediately adjacent were heavily overgrown and obscured by modern dumping, but the area was subsequently cleared for car parking in 2005 revealing two blocked doorways in the front wall, both set about one-third of the way in from each end (not shown on Fig 142). Sometime between 1888 and 1911 the building was extended at the front by a two-celled rectangular structure, here called buildings 17a and 17b. This structure is described in sections 6.2.1 (electricity generation) and 6.2.6 (buildings associated with carpentry and coopering) below.

Stable and/or Cart House (building 20)

The Bigland Estate map of 1796-9 (Fig 3) shows a rectangular building north-east of the 'large' charcoal barn, facing the road which led to the then bridge across the River Leven. The use of the building at this time is not known, but the present report has suggested (this section above) that it may have been the ironworks stable and/or cart house. The main reasons for putting forward this identification are its proximity to the road and the presence on the map of two small paddock-like enclosures behind the building, but other functions are possible. According to the 1863 sale and 1926 factory plans (Figs 6 and 9), it later had a small outshot built against the centre of its rear wall, and was in use as a 'Joiners' or 'Carpenters Shed'. In 1926 it possessed the building number 20, which for the purposes of the present report is also the number applied to its earlier phases.

The structure is now ruinous and heavily overgrown, with only the rear (north-east) wall, and part of the south-east and the stub of the north-west gable walls of the original ironworks

building surviving (Figs 18 and 142). These are built of coursed slate rubble, measure 0.7m thick, and stand to a maximum height of about 2m; they also contain various openings, many now blocked and some of which seem to relate to the later history of the building as a carpenter's shop (buildings associated with carpentry and coopering, section 6.2.6 below). The building measures 16.28m long; its width is uncertain as the gable walls are incomplete, but the suggestion of a slight scarp inside the north-west end wall suggests it was in the order of 7.5m broad. The better preserved south-west end wall survives for 4.28m, but lacks its gable and has evidence for two off-centre doorways: the more northerly door opening is 1.08m wide, but the more southerly opening is now only represented by its northern reveal. Both doorways lack lintels.

Fig 18. The rear wall of the ironworks stable and/ or cart house viewed from the north-east. (Christopher Dunn, July 2005)

Forge (building 103)

There is no definitive evidence for the position of the forge which the iron company operated alongside the blast furnace, but the present report has suggested (this section above) that it was most likely to be the northernmost of the six buildings shown on the 1796-9 Bigland estate map (Fig 3). The map depicts the building as rectangular, aligned roughly north-west to south-east, and with its northern gable wall abutted by a smaller, square structure, offset slightly towards the north-east. It is conceivable that the latter is a chimney stack; although incapable of proof on the evidence available, if true it would suggest that the wheel driving the bellows and/or hammer was positioned against either the south-west or south-east wall.

6.1.3 Field Boundaries

The 1796-9 Bigland estate map (Fig 3) shows the area north of the ironworks (which later formed the heart of the gunpowder factory) divided up into a series of fields. The present investigation has identified two features which seem to correspond to boundaries shown on the map: the first is a ditch up to *c* 4.5m wide and 0.8m deep leading down towards the river between preparing house no. 1/cartridge-press house and the low press house (Fig 142), corresponding to the position of the boundary between fields labelled 'cc' and 'cs' on that map; the second a scarp immediately south-west of the boiler house at the higher stove complex (Fig 82) which closely matches part of the course of the boundary between fields 'cc' and 'cw', and presumably originated as a lynchet.

6.1.4 Charcoal-Burning Platforms

The survey identified seven charcoal-burning platforms (also called pitsteads) within that part of Bigland Woods immediately adjacent to the upper reaches of the gunpowder works headrace. Similar platforms may exist across the whole stretch of hillside above the works, but the present survey examined only that area of woodland situated between the headrace and the footpath leading from Low Wood hamlet to Brow Edge Road. All the pitsteads are

likely to be broadly contemporary. They probably also pre-date the foundation of the gunpowder works as the Lowwood company would undoubtedly have objected to charcoal clamps being fired so close to the works due to the danger of sparks being blown across the factory.

Three of the platforms lie at the foot of the valley side adjacent to the headrace; the remaining four are positioned on the steeply-sloping valley side behind (Figs 131 and 142). As is typical of this monument type when found on sloping ground, all consist of a rear concave scarp terraced into the slope and a convex apron-scarp to the front built up with material excavated from the rear to create a level platform area. The larger platforms now appear almost oval in plan, measuring up to *c* 10m long by 5-6m across, but slumping and erosion means they are likely to have been more circular when first built. All are now overgrown with trees or scrub rhododendrons.

6.2 Phase 2. Lowwood Gunpowder Works

6.2.1 The Power Systems

Water was undoubtedly the main source of power at Lowwood throughout the lifetime of the gunpowder works. In the main it was used to generate mechanical power to operate machinery - initially exclusively by means of waterwheels, but after 1872 via the medium of water turbines also. From the 1860s it was also used to generate hydraulic power to operate presses, and sometime between 1889 and 1910 began to be used to generate electricity (again via water turbines) to provide lighting.

General overviews of the system of weirs and leats and of the use of turbines and hydraulic power at the works are given below, although more detailed information will be found included in the descriptions of the individual buildings which the waterwheels, turbines and pumps served in sections 6.2.3, 6.2.4 and 6.2.6. Electricity generation, however, is dealt with in detail below, and nowhere else in this report.

A number of boiler houses are also recorded at the works, but seem to have been mostly for heat generation in connection with drying gunpowder, warming dressing-rooms, and drying timber. Four such examples are described in association with the buildings they served in sections 6.2.3 (stoves) and 6.2.6 (women's dressing-room and stave-drying shed). The purpose of a fifth boiler house recorded in 1863 - apparently in association with the 'later' packing house - is unclear, but in like manner it is discussed alongside that building in section 6.2.3. An oil engine was introduced to the works *c* 1910 to augment the power output of the sawmill turbine; it, too, is described in section 6.2.6 in connection with the discussion of the sawmill.

Weirs and Leats

The present report has argued (section 4.2 above) that in 1799 the gunpowder company constructed a new weir across the River Leven about 200m upstream of the ruinous Stang End weir, and lengthened the old ironworks headrace accordingly. The Stang End weir plus another, earlier, unnamed but already disused, example (section 6.1.1 above) seem simply to have been abandoned thereafter, and played no part in powering the new works. According to George Shackley, in the 1920s the gunpowder weir was called Eel Dams by the workforce (information from Mike Davies-Shiel); it is not clear if it was always known as such, but it is

the name that will be used to refer to it in the present report. All surviving weirs and leats are shown on Fig 142.

At the southern end of the works, the covered section of the former headrace to the blast furnace was maintained by the gunpowder company purely as a bypass channel rather than as a source of power (Figs 131-2). This means that effectively, measured between Eel Dams weir and the start of the bypass channel, the length of the gunpowder headrace was about 650m. The headrace fed a number of subsidiary leats arranged roughly at right angles to it, all of which took water to individual process buildings and thereafter discharged back into the river. When the gunpowder works opened for business in 1799 there seem to have been three such subsidiary leats (Fig 132) powering, in turn, what became known as the higher corning house, the sawmill, and incorporating mills 25/26 plus the 'earliest' preparing house (section 6.2.3 below). In all likelihood the lowest of these three channels represents an adaptation of an existing leat to the ironworks forge (section 6.1.2 above), but the other two were both new installations. These two new subsidiary leats discharged straight back into the river (that to the sawmill via a covered tailrace), but the adapted leat after leaving the preparing house became in effect the main tailrace, and received the discharge from the by-pass channel emanating from the disused blast furnace.

Before 1846 (Fig 133), an additional branch had been taken off the higher corning-house leat in order to power a second corning house sited further downstream (lower corning house, section 6.2.3 below), and three new subsidiary leats taken off the lower stretch of the headrace to power additional incorporating capacity (one of these quickly subdividing into three channels so as to supply six mills in total); around 1859 (Fig 135) an additional cut was made between the start of the tailrace and the river in order to provide power to a second preparing house (preparing house no. 1, section 6.2.3 below), whilst between 1861 and 1864-5 (Figs 135 and 136) two further subsidiary leats were constructed across the narrow spit of land between the headrace and river at the top end of the works - the first for a new reel and glaze house, the second for a resited corning house (reel and glaze house and high corning house, section 6.2.3 below). All subsidiary leats initially powered waterwheels at the process buildings they served, but after 1872 some of the wheels were replaced by turbines (turbine power, this section below). The final addition to the system of subsidiary leats seems to have occurred between 1889 and 1910 when a covered channel was reportedly constructed between the lowest leat (that to the incorporating mills 25/26) and the covered bypass to power a turbine which alternated between generating electricity and operating a stave-hollowing machine (electricity generation, this section below); EH located no trace of this last leat during field investigation, nor is it depicted on any map; consequently it does not appear on Figs 139-42.

The present Eel Dams weir seems to be largely the original 1799 structure, although undoubtedly periodically repaired. It is essentially a stone construction, although the top was capped in concrete *c* 1965 in order to raise the level of water in the headrace. In plan it is straight (in contrast to the V-shape of some timber weirs), and lies at an angle across the river in order to channel water into the mouth of the headrace on the left bank. It is approximately 80m long, and incorporates a fish pass at its northern end adjacent to the right bank.

The headrace which the weir feeds was originally stone-lined, except for the first *c* 225m of its eastern side where it was cut through solid rock (Fig 19). The change in construction technique corresponds to a noticeable kink in the course of the race (Fig 142), and the kink (close to the position of the later reel and glaze house) probably marks the point where the gunpowder company's extension deviated from the line of the upper section of the earlier ironworks headrace which was subsequently abandoned and filled in. Much of the stone lining of the existing headrace has collapsed and/or been replaced in concrete since 1952/3 when the race began to be used to generate hydro-electricity (section 6.3.2 below), but stretches of original walling still survive in places, most noticeably on the east side between the reel and glaze house and the lower stove (Fig 20); shorter stretches also survive on the west bank, most importantly around the higher stove where a flight of stone steps descends into the race and seems to be part of a small dock for delivering powder to and from that complex by boat; the steps are shown in detail on Fig 82, and the evidence for use of a boat on the headrace is discussed more fully in section 6.2.9 below.

Fig 19.
The rock-cut upper section of the gunpowder headrace at its junction with the subsidiary leat to the reel and glaze house. (NMR DP003489)

Fig 20.
The original stone-lining to the east side of the headrace between the reel and glaze house and lower stove. The walling is now only visible when river levels are low; the modern winter water level in the headrace is shown by the scour mark in the leaf litter on the bank above the wall. (NMR DP006451)

Most of the subsidiary leats are now isolated and/or infilled in order to ensure that as much as possible of the water entering the headrace reaches the modern hydro-electricity station. Only the leats to (in order from north to south) the reel and glaze house, higher corning house (converted in 1863 into the glazing house), lower corning house, sawmill and incorporating mills 35/36 still carry any water, although most of those to the other incorporating mills survive at least in part as dry channels. Those to the high corning house, incorporating mills 33/34 and preparing house no. 1, however, have been completely infilled, and that to incorporating mills 25/26 and preparing house no. 2 buried and/or re-routed in order to supply the modern hydro-electricity station. There is no field evidence for the present condition of the covered leat reportedly constructed between 1889 and 1910. Only those leats for which there is still surface evidence are described further below.

The subsidiary leat powering the reel and glaze house extends for no more than 25m between the headrace and river. Its original junction with the headrace has been much modified (Fig 19) as this was rebuilt in the 1960s when the latter was relined in concrete (the leat was presumably maintained rather than blocked off at that time in order to act as an overflow channel in periods when too much water entered the headrace), but the stone sides and floor of the leat between the modern sluice and the rear curve of the waterwheel-pit are faced in concrete (Fig 21), which by comparison with other leats on the site (for example, the glazing-house leat, this section below) can be dated to 1928/9. In contrast the side walls of the wheel-pit and those of the tailrace all survive as bare stone as originally built. An artificial spit of river cobbles extends out into the Leven on the north side of the tailrace mouth; this existed by 1888, and was constructed to protect the waterwheel from damage when river levels ran high. Wheel-pit and spit are both discussed in more detail in section 6.2.3 below (reel and glaze house).

Fig 21. The reel-and-glaze-house leat and waterwheel-pit from the south-east. Note the steel girders (one obscured by the fallen tree) for the tramway bridge. (NMR DP003484)

The subsidiary leat to what was originally the higher corning house (in 1863 converted into a glazing house), plus the branch off it powering the lower corning house, are both reasonably well preserved; both also contain running water although the volume is much reduced as the take-off from the headrace is now blocked by concrete (Fig 142). The first of these leats is a cut channel, stone-lined throughout its length apart from the final 6m before the corning/glazing house (Fig 68) where it has been relined in concrete (probably in 1929 when the glazing house was modernised and the waterwheel-pit adapted to accommodate a turbine). As the corning/glazing house is sited immediately adjacent to the river bank, there is only a very short tailrace, bridged by a stone slab in order to permit access to the basement levels within the building. The wheel-pit plus the wheels and turbines which occupied it are again all discussed in more detail in section 6.2.3 below (glazing house).

The subsidiary leat which comes off the higher corning-house/glazing-house leat to supply the lower corning house is similarly stone-lined, but for much of its length is raised above the surrounding ground surface (Fig 22) in order to maintain a level and deliver a sufficient head of water at its destination; each side consists of two stone walls spaced *c* 1.41-1.94m apart retaining an earthen/rubble core, plus an additional outer revetment of earth. Almost immediately after the take-off from the glazing-house leat, the lower-corning-house leat enters a 34m long covered section which ends when the leat re-emerges from beneath a concrete tramway-bridge which crosses its line at a skew angle. A small-bore iron pipe is visible on the floor of the leat extending for 4.3m beyond the edge of the bridge; it presumably connects with a length of pipework which protrudes from the other end of the leat's covered section near the take-off point, and turns through 90° towards the south-east to continue for 5m on the floor of the glazing-house leat. The pipe's function is unknown. About 6m below the tramway bridge, a pair of opposed recesses marks the location of a former sluicegate. 18m further on, a slot in the upper level of the north wall allowed excess water to discharge back into the river; this slot presumably originally connected with a small wooden launder carried on a stone support as indicated by a pile of collapsed stonework on the river bank opposite the slot. At the lower corning house, the stone-lined section of the leat ends at a second sluicegate (the timberwork of which is still partly extant) marking the

Fig 22.
The final section of the leat to the lower corning house, looking south-west towards the corning house (visible at centre frame). (NMR DP003477)

Fig 23.
The infilled waterwheel-pit at the lower corning house mark IV. (NMR DP003476)

transition to a now vanished elevated wooden launder which in turn would have fed a pentrough controlling the flow of water onto the corning-house waterwheel. This final section of the leat's course between the sluicegate and wheel-pit is shown in detail on Fig 62: the launder was evidently supported by at least one brick pier which now lies (?)collapsed beneath it, but all trace of the launder itself and pentrough have disappeared. This means that the shallow water which still flows along the leat spills out over the concrete floor of the belt-drive house attached to the rear of the extant mark IV corning house (Fig 23), before seeping away down the side of the wheel-pit which in consequence is largely infilled with débris. Water exited the wheel-pit via a covered tailrace, the only evidence for which now is the outfall - a simple stone-arched culvert (Fig 24) in the river bank in line with the end of the wheel-pit.

Fig 24. The outfall of the tailrace from the lower corning house. (NMR DP003524)

The subsidiary leat to the sawmill is similarly stone-lined and built up above the surrounding ground surface in order to maintain a level. Its connection with the headrace was severed when the latter was relined in concrete; the first *c* 12m of its course also lies buried beneath concrete blocks dumped at the same time to provide revetment for the side of the heightened race. However, the leat still carries a shallow depth of water: this originates as leakage from the headrace a little upstream of the leat, and enters the leat through a breach in its north-east side wall. Besides flowing along the floor of the leat, much of the water also spills out through a second breach in the opposite wall and collects in a large pond or drainage lagoon (a relatively modern feature) whose western edge has been dammed so as to channel the overflow from it back into the sawmill waterwheel-pit through the collapsed rear wall of that building. The leat would originally have fed a pentrough controlling the delivery of water onto the sawmill waterwheel, but the OS second edition 25-inch map (Fig 8), surveyed in 1911, shows that this had then already been superseded by the present small, concrete-lined, header tank - probably in 1910 when the waterwheel was replaced by a Gilkes water turbine. Tank, waterwheel-pit and turbine (the latter still surviving *in situ* within the pit) are all described in more detail in section 6.2.6 below in connection with discussion of the sawmill. There is now very little evidence for the line of the tailrace (which must always have been culverted as it is not depicted on any of the historic maps of the works), but it seems likely that a short length of shallow ditch in the river bank behind the press house marks its outfall (Fig 142). The fact that this ditch is now completely dry, however, suggests that the culvert may have collapsed or sprung a leak, and that water entering the tailrace from the wheel-pit now drains out into the underlying gravels before reaching the river.

Of the various subsidiary leats to the incorporating mills, only parts of those to mills 27/28 and to mills 33/34, 35/36 and 37/38 still survive – the latter three all in effect being branches of the same leat.

The short leat to incorporating mills 27/28 comes off the main headrace immediately before the latter enters its covered section leading to the former blast furnace. Recesses in the side walls close to the junction indicate the position of a former sluicegate, although all

trace of the timber supports and gate has now vanished. A broken bedstone which lies across the leat at this point presumably originates from the mills themselves and was placed here to form a footbridge, but only the eastern edge of the stone is visible as for the next 8m the leat is infilled by material dumped in the 1950s/1960s as part of the massive embankment retaining the heightened headrace to the hydro-electricity station. Behind the extant mill 28 mark II, however, the leat survives as an elevated dry channel whose sides are each formed of double stone walls retaining an earthen and rubble core; it then turns a right-angle to approach the rear of the wheel-pit which lies on the west side of that mill, and where there are still the remains of the wooden pentrough installed in 1928 when mill 28 was rebuilt and its neighbour, mill 27, demolished. The wheel-pit itself is now infilled, as is the tailrace leading from it, the only evidence for which seems to be a concrete fillet overlying what is presumably its southern edge in which are three square holes which must indicate the positions of the uprights for a guardrail. The pentrough, however, is illustrated and discussed in more detail in Figs 50 and 51 in association with mill 28 in section 6.2.3 below (incorporating mills 27-38).

As with the sawmill leat, the start of that supplying incorporating mills 33-38 was blocked off when the headrace was relined in concrete and revetment material dumped along its outer edge, but the upper courses of the side walls of the final 8m or so of the short branch leat to mills 33/34 are still visible, as is much of the course of the embanked side walls of the second branch leat (to incorporating mills 37/38) which had to be carried across the access track to mills 35/36 on a wooden launder. The leat to mills 35/36 is the only one of the three branches which still carries water; it was relined and heightened in breeze blocks when a turbine and dynamo were installed in the wheel-pit between the two mills after the gunpowder works closed. The turbine is no longer used, but the leat still carries water for fish breeding-tanks housed in the basement beneath mill 35 mark II; water enters the leat through a pipe buried beneath the material revetting the side of the headrace. Further details on the form of this leat, principally the addition of the header tank to feed water to the turbine, and on the turbine itself, are included in section 6.2.3 below (incorporating mills 27-38)

Turbine Power

The Lowwood company acquired its first water turbines in 1872: 5.2kW and 14.9kW units purchased from the firm of Williamson of Kendal, although there is no record of what either powered. In 1903 the company made enquiries of the firm of Wright, Heap and Westwood (also of Kendal) apparently this time in connection with a 12.7kW unit for the glazing house, but there is no evidence confirming that the purchase went ahead (if it did, the turbine was replaced in 1929 by a more powerful unit: see below). In 1910 the company took delivery of a further two turbines from the firm of Gilkes & Co of Kendal (who had bought Williamson in 1881 (Crocker 2000, 96)): the first was a 29.8kW ‘Trent’ unit, manufacturer’s no. 2065 (Fig 102), for use at the sawmill; the second a 4.5kW ‘Vortex’ unit, manufacturer’s no. 2145, intended for the generation of electricity (section 4.2 above and this section below).

In 1928 ICI, with whom the Lowwood company was by now incorporated, purchased a 13½-inch (343mm) type CA ‘River’ turbine from the firm of J J Armfield, based in Hampshire. This may well be the same unit as that which still exists on site (although now disused) installed in the basement of the demolished mark I incorporating mill 36 (Figs 45, 55 and 56) where

it was used to power an electricity generator, but if so it must have been relocated to its present position after 1935 (incorporating mills 27-38, section 6.2.3 below). Two possibilities for its original siting are the glazing house, which by 1933/4 was powered by an 18.6kW turbine of unknown manufacture (most probably installed *c* 1929 when that building was remodelled), and incorporating mills 25/26, where field evidence indicates a turbine was installed at some point after 1928 in the central waterwheel-pit following decommissioning of that pair of mills (section 6.2.3 below). By 1933/4, ICI also employed a small 0.37kW steam turbine to blow hot air around the higher stove house (section 6.2.3 below); this unit was again most probably installed in 1929 as part of the general modernisation programme.

Gilkes turbine no. 2065 still survives *in situ* at the ruined sawmill: it is described in detail in conjunction with the sawmill in section 6.2.6 below. The surviving Armfield turbine is likewise described in greater detail as part of the description of incorporating mill 36 in section 6.2.3 below.

Hydraulic Power

The Lowwood company seems first to have used hydraulic power in late 1861 when it bought an hydraulic press for installation at the low press house (before this date, any press at the works was probably hand-operated); hydraulic power for the new press was generated by pumps housed adjacent to the sawmill and driven from that building's waterwheel. In 1865 the high press house opened, drawing power from pumps operated by the high corning-house waterwheel. In both cases the pumps were sited close to the wheel which drove them, and water piped under pressure over considerable distances to the presses. When the company built a cartridge-press house in 1886, they installed an hydraulic accumulator next to it raised by pumps driven from a wheel between the two buildings; however, the wheel soon proved inadequate to the task, and possibly as early as 1888 the accumulator was instead being powered by a new set of pumps installed at, and driven by, the sawmill waterwheel. Pump houses and accumulator are all described in more detail in the sections covering the process buildings served in sections 6.2.3 and 6.2.4 below.

Electricity Generation (Building 17a)

Electric lighting was introduced to Lowwood sometime between 1888 - when the merits of having it were first discussed - and 1910 when the company purchased a Gilkes 'Vortex' 4.5kW water turbine specifically to perform the task (section 4.2 above). The 1926 factory plan contains no information which might suggest where this turbine was installed, but according to George Shackley (who worked at Lowwood between 1922 and 1928) it drove a dynamo accommodated in the southern half of a two-celled building which the OS second edition 25-inch map (Fig 8) shows attached to the outside of building 17 opposite the north-east gable of the Clocktower complex (information from Mike Davies-Shiel). Strangely, this building does not seem to be represented on the 1926 factory plan (compare Fig 9). Whether it housed a turbine before 1910 is not known. According to Shackley the turbine was powered by a covered leat coming off the branch supplying incorporating mills 25/26.

The southern half of the building housing the turbine and dynamo is here numbered building 17a, while the northern half - which housed a stave-hollowing machine - will be numbered 17b (described in section 6.2.6 below). Since Shackley stated that there was insufficient

power in the turbine to operate both the dynamo and stave-hollower at the same time, this raises the possibility that electricity was later generated elsewhere. EH has found no historical evidence in support of this suggestion, but intriguingly field evidence does indicate that a turbine was installed in the former waterwheel-pit between the decommissioned incorporating mills 25/26 sometime after 1928 (section 6.2.3 below).

Only part of the footings and concrete floor of building 17a now survive. On the ground, a low stone wall is traceable running away south-west from the southern corner of building 17 and returning for a short distance to the north-west. When surveyed in 2004, the interior of the area so defined was heavily overgrown and masked by brash, and all that could be seen was a concrete floor *c* 4.7m wide by 6.88m long. However, subsequent clearance for car parking in 2005 exposed evidence for a machine bed (not shown on Fig 142). There is now no surface trace of the covered leat mentioned by Shackley.

6.2.2 The Preparation and Storage of Raw Materials

Cylinder Houses, Charcoal Stores and Coppice Barns (buildings 7, 8 and 17)

When Lowwood opened for business in 1799, the company bought its charcoal from external suppliers, but from 1801 until probably the early 20th century it manufactured its own charcoal on site using the cylinder or retort method which resulted in a better quality product. After 1801, therefore, in addition to charcoal stores, the works must also have possessed sheds and barns for sheltering the retorts and for storing supplies of coppice wood (section 4.2 above). The siting of charcoal barns within gunpowder works was regulated by the 1772 Gunpowder Act, one of whose clauses stipulated that no charcoal store could lie within 20 yards (18.3m) of any mill or magazine in case the charcoal self-combusted (Cocroft 2000, 28) – as happened at the New Sedgwick factory in 1884 (Dunn *et al* 2003, 38).

The earliest evidence for the location of any of these structures is the 1863 sale plan (Fig 6), which depicts a 'Retort Ho[use]' (building 7) close to the river at the southern end of the site, a 'Wood Warehouse' (building 8) adjacent to it, and an L-shaped building (building 17) a little to the east annotated simply as 'Charcoal' (these latter two are presumably the contemporary coppice barn and charcoal store). The schedule in the accompanying indenture mentions 'three cylinder houses', but in the absence of separate retort houses shown on the plan, this could be interpreted as meaning either that building 7 then contained three charcoal cylinders or was divided into three compartments.

Comparison with the 1846 plan (Fig 4) suggests that building 7 was a recent replacement of an earlier structure (the versions of building 7 shown on the 1846 and 1863 plans will here be distinguished by the suffixes mark I and mark II), but that both other buildings existed by 1846. Building 8 must have been put up in or shortly after 1801 (when the company began producing its own charcoal) as it is not depicted on the 1796-9 Bigland estate map (Fig 3), but building 17 is shown on that map and had probably been erected by the earlier ironworks company specifically as a charcoal barn ('small' charcoal barn, section 6.1.2 above). However, if the gunpowder company were continuing to use the barn in the same capacity, legally charcoal could only have been stored in the range forming the foot of the 'L' as the gable of the northern wing stood only *c* 17m from the nearest incorporating mill.

The 1926 factory plan (Fig 9) shows the same three buildings largely unaltered in plan from 1863, but the retort house (labelled 'Cylinder House' on the plan) is seemingly the only one to have kept the same function: what had been the coppice barn (building 8) was now the authorised charcoal store, while the old charcoal store (building 17) was in use only as a general store for casks and other items. The proximity of the cylinder house to the resited charcoal store, however, and the fact that the former, if functioning, would have presented a grave fire risk to the latter, suggests that the retorts were actually disused at this date and that charcoal was once more being sourced externally. Indeed, according to George Shackley, the retort house had become a hay store by the 1920s, and was finally demolished in 1928 (information from Mike Davies-Shiel). Building 8 was still apparently being used as a charcoal store as late as 1933/4, for page 1 of the MMB states that charcoal then arrived at the mixing house by tram 'via [the] weighbridge' (building 10a, section 6.2.6 below).

Of the structures described, building 8 is the only one still roofed and upstanding (Fig 25), having been converted since the works closed to a domestic residence called 'The Charcoal Store'. It is a tall, single-storey building, gabled to the south-east and north-west and constructed of roughly-coursed slate rubble with a shallow-pitched slate roof, although the shallow outshot which all the historic maps and plans (Figs 4 and 6-9) record along part of its north-east side is unroofed and partly buried beneath the embankment retaining the modern leat to the hydro-electricity station (Fig 142). Its external appearance was radically altered when it was converted to a house: existing openings were altered, new doorways and windows inserted, the interior sub-divided and a double-flue chimneystack inserted. All of the inserted, and one of the original, openings have timber lintels faced with protective slate tiles.

Fig 25. 'The Charcoal Store' (building 8) viewed from the south. (NMR DP003456)

Straight joints indicate that the building was constructed in at least two phases. The earliest part is the north-west half, which measures 7.97m long by 5.72m wide and has walls 0.6m thick. All the walls have modern inserted doorways and windows, but original features include four slit vents, all now blocked, two in the north-west gable wall and two in the south-west side wall, and all set in the lower half of the wall with slate lintels and flush sills; there is also a small square ventilation opening, now blocked, set centrally at the base of the gable wall. These openings indicate that the building was erected specifically for storage, and probably served as a coppice barn from new. Its roof is supported by two purlins per side, the shaped ends of which project out from the gable wall. It must have been entered through a doorway in the south-east gable wall; this gable wall was retained when the building was almost doubled in length, but is now masked. The extension, which measures

7.4m long, abuts the earlier structure and maintains the same width and height. The only original features are a tall cart entry, 2.5m wide, in the centre of the new south-east gable wall, and a taking-in doorway immediately above it. The cart entry, its lower half blocked on its recent conversion into a window, has, because of its width, a timber lintel faced with slates; the taking-in doorway, also now blocked, has a massive, irregularly-shaped lintel (Fig 25) not unlike those used on the new saltpetre refinery erected in 1849 (this section below). Map evidence (Fig 4), however, shows that the extension must pre-date 1846.

RAF aerial reconnaissance photographs (*eg* NMRC 541/525 frames 3306-7) show that building 17 also survived the closure of the factory in 1935, and was still standing and roofed in 1950. However, in 1952/3 it largely disappeared beneath the massive embankment retaining the re-routed leat to the new hydro-electricity station. Only the front (south-west) wall and the return of the north-west gable are still visible at the foot of the embankment behind the Clocktower complex: these have already been described as part of the account of the ironworks 'small' charcoal barn (section 6.1.2 above). Remains of walls and a concrete floor immediately outside the building are part of a later building also described elsewhere (electricity generation (building 17a), section 6.2.1 above, and stave-hollowing shed (building 17b), section 6.2.6 below).

No above-ground trace of the retort house survives, although according to Tyler (2002, 154) the old cylinders were taken away to be set into the ground for reuse as mooring bollards at the entrance to the Ulverston Canal, where they may still be seen (Fig 26).

Fig 26. Charcoal retorts reused as bollards at the entrance to the Ulverston Canal. (Marcus Jecock, February 2005)

Saltpetre Stores (unlocated and buildings 102a and 11c)

The earliest firm evidence for the site of the saltpetre store or warehouse at Lowwood is the 1863 sale plan (Fig 6), which places it in the southern end of the 'large' charcoal barn erected by the former iron company (section 6.1.2 above). This reuse of the building must have involved some subdivision of the interior and alterations to the number of doorways and previously minimal fenestration, although no evidence survives for this. The schedule in the indenture which accompanies the sale plan records a tram line in association with the warehouse (section 4.2 above); the plan shows that this ran between the barn and the northern end of the refinery.

On the 1926 factory plan (Fig 9) the same, southern, end of the barn is numbered as two buildings (nos. 14 and 15, re-numbered 102a for the purposes of the present report), both still authorised for the storage of saltpetre but also recorded as disused; the tram line had also been lifted by this time. As no alternative dedicated warehouse is identified, the likelihood is that saltpetre was now being imported to the works in its pure state and stored at the

disused refinery. Indeed, George Shackley remembered that saltpetre was stored in the northern end of the more westerly of the refinery's two southern wings in the 1920s (information from Mike Davies-Shiel); the relevant part of the refinery is labelled building 11c on Fig 141. The date saltpetre refining ceased at Lowwood is unknown, but it most probably happened after 1888 for the OS first edition 25-inch map (Fig 7) shows the tram line between the refinery and building 102a still in existence. Perhaps the most likely occasion is 1918 when all the Cumbrian blackpowder works united to form Explosives Trades Ltd, creating for the first time a single management structure and the possibility of specialisation between individual factories (certainly by 1934 Lowwood was no longer refining saltpetre but was importing it in a pure state from its sister factory at Gatebeck (MMB, 3)). However, such specialisation could well have started earlier, for Lowwood had been owned by the Wakefield company (who operated Gatebeck) since 1882 (section 4.2 above).

Although the site of the saltpetre store prior to 1863 is not known, it was most likely accommodated within buildings 102a, or alternatively in the old blast-furnace complex (building 100) which served as the refinery until that building was demolished and replaced by the extant refinery in 1849.

No evidence for the tram link between buildings 102a and 11 survives on the ground, but it is obvious from field evidence, particularly the lie of the land, that it must have entered the main block of the refinery at first-floor level. It is discussed in more detail in association with description of the saltpetre refinery (this section below).

Sulphur Stores (unlocated and building 11d)

No sulphur store is labelled on either the 1863 sale or 1926 factory plans (Figs 6 and 9). In consequence, for much of the lifetime of the works the location of this building is unknown. According to George Shackley, in the 1920s sulphur was stored in the southern end of the more westerly of the two southern wings of the Clocktower complex (information from Mike Davies-Shiel). Although the 1926 factory plan does not name building 11 as authorised for such use, Shackley's information nevertheless makes excellent sense logistically, for a tram line is depicted running west from the wing's gable wall to join another line returning north-east past the composition (*ie* preparing) house. The information also fits well with a statement regarding the practice at the works in 1933/4 contained on page 1 of the MMB, to the effect that charcoal and lump sulphur then arrived at the composition house 'in bags by bogie from the Charcoal and Sulphur Stores via weighbridge'; the weighbridge in question is undoubtedly building 10a situated adjacent to the second tram line at its junction with a spur from building 8, then used as the charcoal store (this section above). For the purposes of the present report, the part of building 11 latterly used as the sulphur store will be called 11d (Fig 141).

In the absence of any mention of a sulphur warehouse on the 1863 sale plan or in any of the documents which comprise the HF collection, Lowwood must always have stored its sulphur either at the saltpetre refinery (building 11 and its predecessor, building 100), or, just possibly, one of the other buildings nearby. This would certainly make sense if the sulphur also had to be purified before use, as mention of a brimstone refiner in the 1851 census returns implies was the case in the 19th century (saltpetre refinery, this section below).

Saltpetre Refineries (buildings 100 and 11)

Saltpetre is the old name for potassium or sodium nitrate (chapter 5 above). When Lowwood opened for business in 1799, the saltpetre it used would have come from Bengal. Bengal saltpetre was a natural deposit of potassium nitrate imported by the East India Company and sold at auction in London (section 4.2 above). Although partly purified, it was still contaminated with varying amounts (up to *c* 9 per cent by weight in good samples) of sand and other salts, principally sodium sulphate and sodium chloride. These impurities had to be removed before the saltpetre could be used to manufacture gunpowder, or else the quality of the final product could not be guaranteed (Smith 1870, 10-12). Later in the century, Lowwood also made gunpowder from sodium nitrate imported from South America and elsewhere.

There were a number of established techniques for refining saltpetre, but all were essentially variations on a theme and relied upon the fact that saltpetre, unlike most other salts, is more soluble in hot water than cold. At the end of the 19th century, the three main techniques were known as the Spandau, French and English Processes (Guttman 1895, 32-6). The English process (which was that employed by the British Government at the Royal Gunpowder Factory at Waltham Abbey) was certainly in use by the third quarter of the 19th century (Smith 1870, 10-21). In essence, it involved boiling a solution of 'grough' (impure) saltpetre in vats for some considerable time, following which the hot solution was run off into wooden crystallising pans. The solution was stirred constantly as it cooled to promote the formation of fine crystals, which were drawn up on the side of the pans and shovelled onto draining shelves before being washed three times in a second set of wooden vats. Once the final washing water had been drained off (all washing water was recycled), all but the bottom six inches (150mm) of saltpetre (which was too wet) was removed and placed into bins, where, after a few days it contained only 3 to 5 per cent moisture and was ready for use. It is not clear at what date the English process was perfected, but an early variant of the French process is described as the 'modern method' in an English technical treatise published by Abraham Rees in 1819-20 (Cossons 1972, 422). It differed from the English process in that the grough saltpetre was washed three times in cold water prior to being boiled. The hot solution was then discharged into coolers and stirred, causing the precipitation of fine feathery crystals of almost pure saltpetre. These were scooped out with a ladle and allowed to drain, and briefly washed once more in cold water before being spread out on a table to dry. The final stage of the process involved drying the crystals further in large basins heated to a temperature not exceeding 120° F (49° C); the contents of the basins were again constantly stirred. After two or three hours, this rendered the saltpetre almost pure and brought it to the consistency of fine sand.

It is not clear what technique Lowwood followed, but mention of an old boiler which the company acquired from the previous lessees of the factory in 1799 (section 4.2 above), combined with Rees' description of how saltpetre refining was generally undertaken in 1819, suggests that Lowwood initially employed the French process. There is no specific information of where this early boiler was located, but it is most likely to have been situated in the old blast furnace complex which had certainly become the saltpetre refinery by 1846 (Fig 4). However, the main part of the blast furnace-cum-refinery was totally rebuilt in 1849,

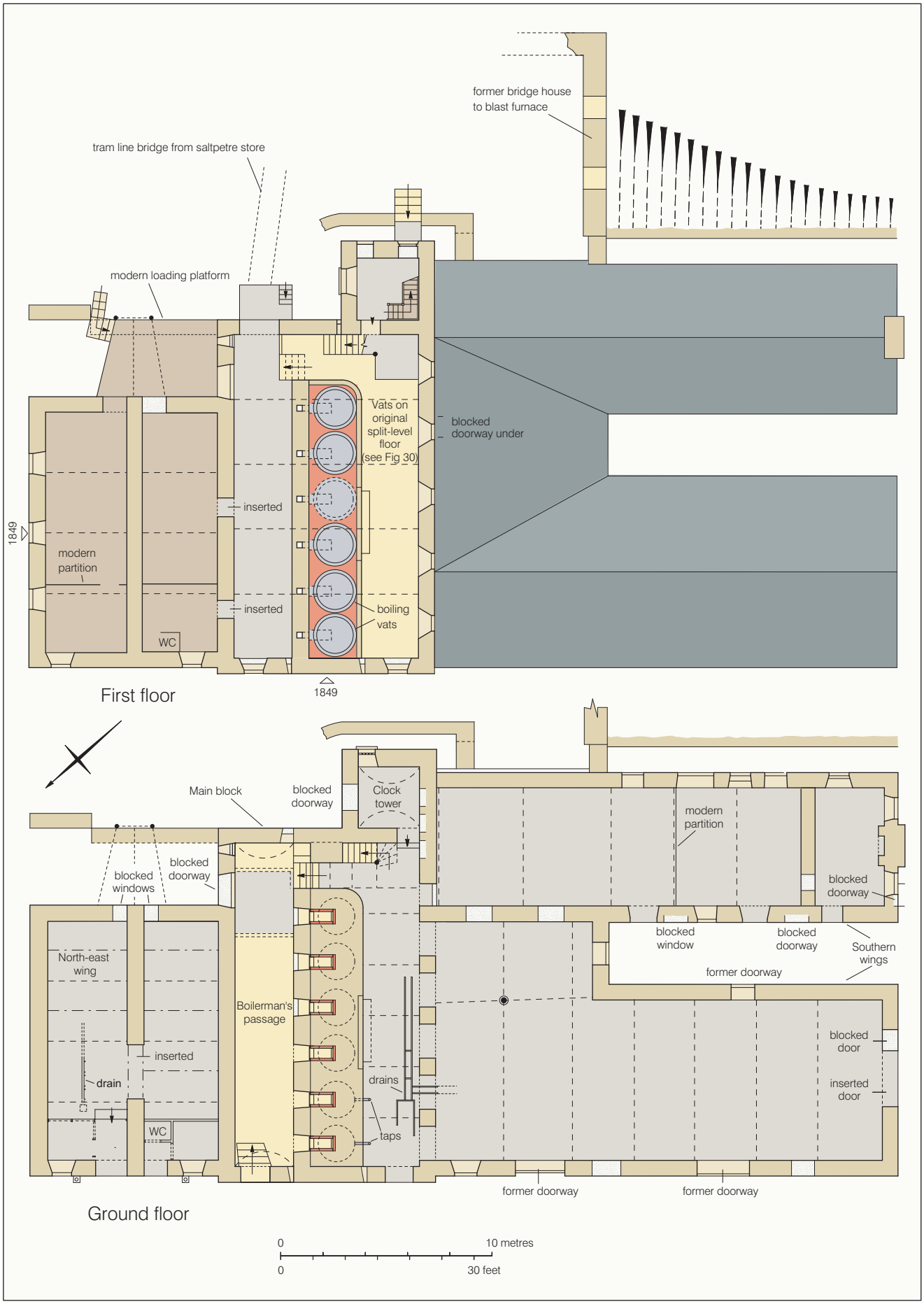


Fig 27. EH plan of the saltpetre refinery (see page xiv for key to conventions)

and all physical evidence for how the process was carried on before this date destroyed. The surviving structural detail, plus the general layout of the building, suggests that from at least 1849 Lowwood operated the English process (see below).

In 1863 when the Lowwood company was restructured and took on limited status, it owned a second saltpetre refinery at Acton Bridge, near Northwich in Cheshire. Lowwood received partly-refined saltpetre from Acton as well as additional supplies of grough saltpetre bought on the open market. However, it appears that Acton saltpetre was refined by the 'washing' or 'sprinkling' system (HF LW/1869/011), and had to be further refined at Lowwood. In April 1869, the company was planning to erect a 'floor and fillings' at Lowwood in order to riddle the Acton saltpetre prior to carrying out this secondary refining (HF LW/1869/017). The purpose of this was twofold: first, to break the saltpetre down as it could congeal into hard lumps if it was stored too long in bags (HF LW/1873/003); and secondly, as a response to a catalogue of incidents in the 1860s when iron objects were discovered in the Acton saltpetre (*eg* HF LW/957/154 and 650a, LW/958/870). The company may have abandoned the washing system in 1871 (HF LW/1871/003); the fate of the Acton refinery after this date is unknown.

The mention of a 'brimstone refiner' resident at Brow Edge in 1851 (Cumbria Family History Society 2003, 100) indicates that at least in the first half of the 19th century, sulphur, too, had to be purified at Lowwood. As the normal method of purification involved heating the grough sulphur and skimming off the impurities (Cocroft 2000, 53-4), it is possible that the operation was performed in a dedicated boiling pan within the saltpetre refinery.

The MMB (page 3) records that by 1933/4 saltpetre was no longer refined at Lowwood, but was imported from the nearby Gatebeck gunpowder factory instead. The closure of the refinery must pre-date the mid-1920s, for according to George Shackley (information from Mike Davies-Shiel) at this time the southern end of the more westerly of the two southern wings was in use as a sulphur store and the northern end as a saltpetre store (buildings 11d and 11c on Fig 141; see also sulphur store and saltpetre store, this section above), while the northern end of the ground floor was turned into a washing and changing area in 1928 with a dining-room above (building 11b on Fig 141; see also section 6.2.6 below). According to Patterson (1995, 15), all of the saltpetre which arrived at Lowwood from Gatebeck was potassium nitrate, not sodium nitrate (the gunpowder made from the two forms of saltpetre was known as N/P and N/S powder respectively (chapter 5 above)). Although the works did turn out N/S cartridges, these were manufactured using powder brought in from the New Sedgwick factory (section 6.2.4 below).

Prior to the abandonment of saltpetre refining at Lowwood, the company also received a small extra income from the sale of 'refuse salt' (waste salts left over from the refining process) which was used as an agricultural fertiliser (*eg* HF LW/957/545 and LW/959/092).

As already stated (this section above), the original saltpetre refinery seems to have been converted out of the blast furnace buildings which the gunpowder company inherited in 1799. It is unclear how much of the blast furnace was rebuilt (section 6.1.2 above), but the

south-west range accommodating the casting house appears to have been at least partly reconstructed as two single-storey sheds before 1846. Apart from their very northern ends, these were both unaffected when the rest of the blast furnace/saltpetre refinery was rebuilt in 1849. They probably functioned as crystallising or washing sheds - both before and after 1849 - very much on the model of similar single-storey sheds erected at the Waltham Abbey factory in 1830 (Cocroft 2000, 53 and Fig 2.37). They are described below as the 'southern wings'.

In 1849 the northern half of the saltpetre refinery was rebuilt to provide larger and more up-to-date facilities for the refining process, as well as more spacious warehousing. Of the existing buildings, only the old ironworks bridge house and the southern wings of the refinery were retained, the latter remodelled as necessary to fit in with the new elements. The new structure, as well as being an industrial and commercial advance, was also a statement by the company in its fiftieth year since it included a tall clock tower which was more ornamental than functional in purpose.

The 1849 structure, two storeys high and L-shaped in plan (Fig 27), consists of: a rectangular main block in which (in conjunction with space in the retained single-storey sheds) the processes of saltpetre refining were carried out; a north-east wing containing two separate floors of warehousing; and a five-storey high clock tower attached to one corner of the main block (Figs 28a-d). The date of the rebuilding is given by two datestones: one in the north-west gable of the main block, the other in the end gable of the north-east wing. All the new work has walls of coursed slate rubble, some with quite substantial coursed-in quoins. It also has roofs of Welsh slate in contrast to the earlier sheds which are roofed with local slate shingles; in addition the L-shaped block has ceramic ridge tiles while the pyramidal roof of the clock tower has lead flashing and a decorative wrought-iron finial incorporating a

Fig 28. Four views of the 1849 saltpetre refinery. Clockwise from top right:
a. The refinery from the east. (NMR DP003501)
b. The refinery from the north. (NMR DP003464)
c. The refinery and earlier southern wings from the south-west. (NMR DP003466)
d. The refinery from the south-east. (NMR DP003468)

weather vane. Most of the openings – doorways, windows and vents – have massive, irregularly-shaped slate lintels, although there are a few with round-arched heads formed from slate voussoirs. The new building was well planned: like the blast furnace which it replaced, it made use of the fall of the land (which is from south-east to north-west) and took account of the positions of nearby buildings to ensure the efficient flow of the successive processes of saltpetre manufacture.

The main block, which is gabled north-west to south-east, has been surprisingly little altered since 1849; the principal changes are the recent insertion of a first floor across the whole of its interior in place of an original split-level first floor, and the demolition above the level of that new floor of the long chimneystack leading from the furnaces on the ground floor (Fig 30). The main block, which has three doorways on the ground floor and one on the first floor, contained a central bank of six boiling vats each set over its own furnace. The furnaces opened off a tall, wide passage with a segmental-arched stone vault and a stone-flagged floor along the north-east side of the ground floor (Fig 29). This passage, the equivalent of what has been termed the 'saltpetre boilerman's foot-walk' in the former saltpetre and sulphur refinery at Elterwater Gunpowder Works, Cumbria (Jecock *et al* 2003, 33), has two external doorways. The doorway in the side wall at the uphill end of the building was conveniently sited for access to and from the adjacent 'small' charcoal barn (building 17), from where the charcoal which fired the furnaces must have been brought. This doorway is now blocked (Fig 37), as is a small window close to it and a second window in the end wall of the passage, both of which provided light to what would have been a gloomy area. The doorway at the other, downhill, end of the passage, which has a rectangular overlight (now without its original small-pane glazing) opens on to an internal flight of stone steps and would have been inconvenient for the delivery of charcoal: it is likely, therefore, to have provided pedestrian access, and, in conjunction with the slit vent next to it and the blocked doorway at the other end of the passage, would have assisted ventilation and draught for the furnaces. A small area of concrete flooring in the passage most probably relates to later use of this part of the refinery as a washroom (men's washing and changing house, section 6.2.6 below).

The six furnaces have all been altered since they were constructed in 1849. Three are now blocked, but it is clear that they all originally had stoking areas with tall round-headed openings off the boilerman's passage, gently-splayed sides, and vaults which dipped down to their inner ends (Fig 30). These stoking areas, since remodelled, were all originally built of stone rubble; they and the furnaces are here numbered 1-6 from south-east to north-west. Furnace 1 has the least altered opening (Fig 29): it is now blocked, but still retains its stone-voussoired arched head which is unaltered but for the insertion of a square vent (also now blocked) immediately above its apex.

Fig 29. The boilerman's passage from the south-east, showing furnaces nos. 1-3 with no. 4 just visible behind the crates. (NMR DP003505)

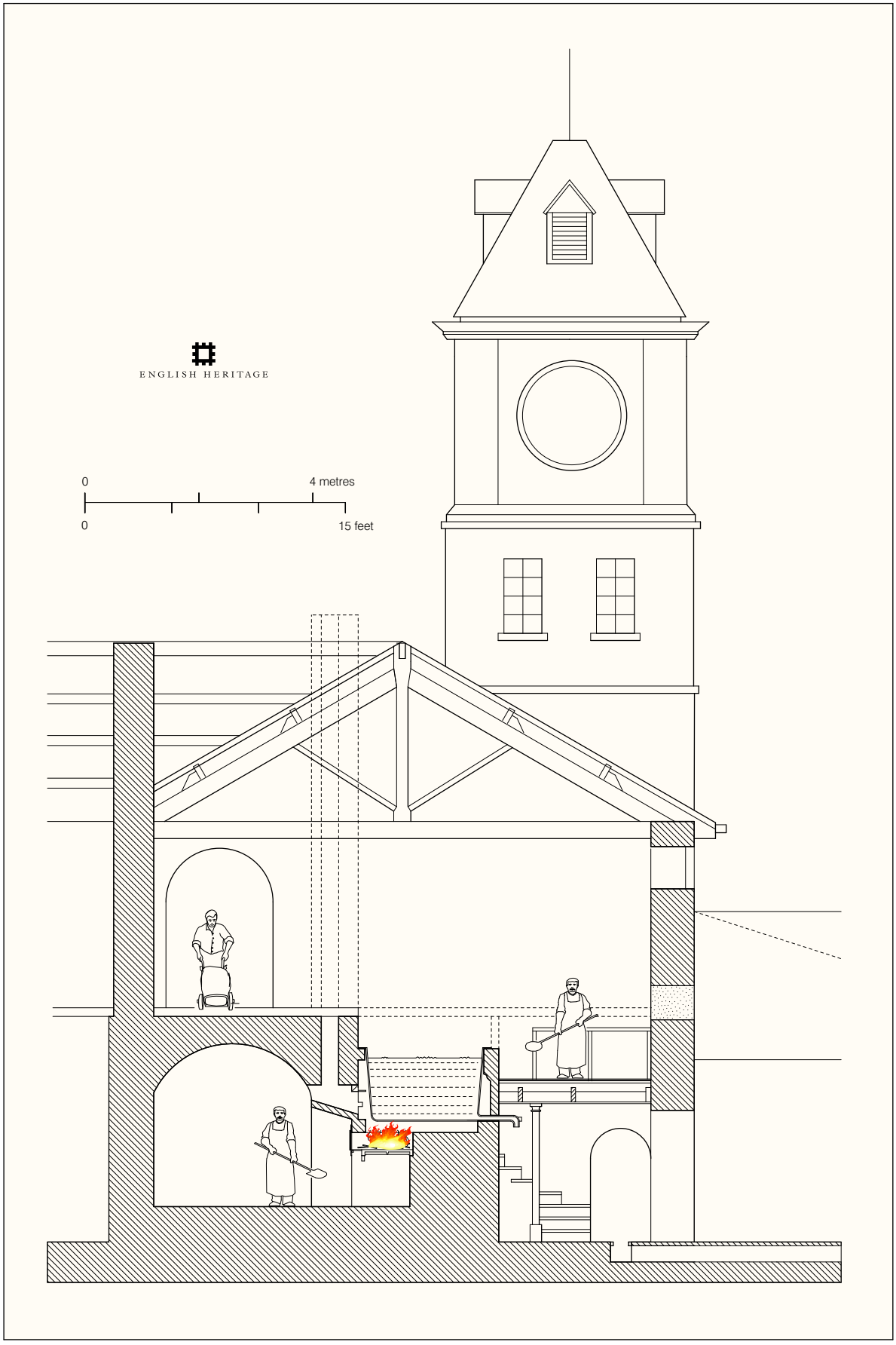


Fig 30. Reconstructed cross section and elevation through the main block of the saltpetre refinery to show the operation of the boiling vats (see page xiv for key to conventions)

Furnaces 2 and 3 also have blocked openings, but little more than the springers of the stone arches survive, and furnaces 4, 5 and 6 - which are the only ones not blocked - merely retain single stone springers. All six stoking areas were modified, probably in the late 19th or very early 20th century, when new iron grates were installed to heat the boiling pans and new airflow patterns created to increase the draw of the furnaces. The work, undertaken in red brick (Figs 29 and 31), involved the substantial rebuilding of most of the stoking areas. The upper parts of the sides and vaults of all but the stoking area of furnace 1 were rebuilt, the flat-topped voids above the vaults, which in places can be seen to have iron straps supporting them (Fig 32), opening into the chimney flues and drawing air from the passage through square openings which are visible either as insertions in the existing masonry or as part of more extensive brick rebuilding. The new iron furnaces, which survive incompletely, have doors which open on to chambers with iron bars over what served as ground-level ashpits (Fig 30). The furnaces heated the bases of cast-iron boiling vats, five of which survive *in situ*, some displaced slightly during the insertion of the new first floor.

Fig 31.
The stoking area and fire-box door to furnace no. 5.
(NMR DP003508)

Fig 32.
The iron straps supporting the flat-topped voids above the furnace vaults.
(Christopher Dunn, March 2005)

The six furnaces were stoked from the boilerman's passage just described, but the boiling vats which they heated were fed with raw materials and tended from an upper floor on the opposite, south-west side of the block (Fig 30). The vats are circular in shape and have gently-tapering sides and flat bottoms (Fig 33). They have 0.15m wide flanges, an upper internal diameter of 2.28m, and are 1.30m deep. The vats are now filled with rubble, and it is not known whether they have perforated false bottoms like their counterparts in the refinery at the Royal Gunpowder Works at Waltham Abbey (see below). Taps for drawing off the liquor are set just above the bottom of each vat. The vats are set in a stone and brick structure within which the flames, heat and smoke

Fig 33.
One of the boiling vats sealed beneath the modern inserted floor of the saltpetre refinery.
(NMR DP003514)

from each of their furnaces circulated before it was drawn up the flues in the long chimneystack behind them. This long stack, which can be seen at its base to have been built of red brick, rose off-centre through the roof of the building (Fig 30). It is not visible on an old photograph (reproduced in Tyler 2002, 136 bottom) taken from the west, but this does show shallow vents in the opposing roof slope, as well as the narrow windows which lit the interior. A small chimneystack survives on the apex of the north-west gable, and since the building required no fireplace, it may have provided extra draw for the hearths of the six furnaces.

The contents of the boiling vats were tended from a stone-flagged floor, 0.56m below the lip of each vat, which was supported by joists set in timber beams carried by cast-iron girders (Fig 30). The upper floor and its vats were open to the roof, some distance above in what would have been a well-ventilated environment; the roof, which spans the full width of the main block, is supported on four king-post trusses. The upper floor was reached in several ways. There were two means of access from the ground floor, the principal one being a flight of steps in the short corridor joining the passages on either side of the bank of furnaces and vats, just inside the south-east wall (Figs 27 and 30). The bottom steps have been removed, but they turned around a slender cast-iron column which supports the cast-iron beams forming the re-entrant corner of the upper floor; the surviving upper flight has brick walls and stone steps. There was also access to this floor from a now lost staircase - which must have been of timber - which rose from within the more easterly of the two single-storey southern wings and through what is now a blocked doorway opposite the vats. This upper working floor was lit from five shallow windows set high up in the south-west side wall, directly under the eaves. As the 1863 plan (Fig 6) shows, grough saltpetre was at one time brought into the building down an elevated tramway from the saltpetre store situated within one end of the former ironworks ‘large’ charcoal barn (saltpetre store, this section above). The tramway led to the large round-headed doorway at first-floor level in the uphill wall of the main block adjacent to the clocktower (Fig 28a and d) - a doorway which now has double doors and a semicircular fanlight, all of them modern. Just within the doorway, there must formerly have been steps to one side leading down to the slightly lower working floor beside the boiling vats, but these are now obscured by the inserted floor. There was a long, narrow room ahead (directly over the boilerman’s passage) which was most probably for storage; two doorways from it into the upper floor of the warehouse area in the north-east wing, however, may well be secondary.

Fig 34. The taps for draining the boiling vats above furnaces nos. 5 and 6 into the filters. (NMR DP003504)

After the saltpetre solution in the vats had been boiled sufficiently, the refining process involved drawing the resultant liquor off into filters. The large cast-iron taps associated with furnaces 5 and 6 survive and project through the rear wall supporting the boiling vats (Fig 34), into a wide

passage; both are complete but for the handles which controlled the flow of liquor. The passage has a concrete floor containing a drain of some age – which by analogy with the layout at Waltham Abbey probably collected both/either the left-over solution from the crystallising pans and/or the washing water (see below) - plus a doorway and a slit vent in the downhill end wall; the rectangular overlight above the door retains its original small-pane glazing. Five tall round-headed openings open from the passage into the more westerly of the two single-storey southern wings beyond (Fig 35), but to understand how this area was used it is first necessary to consider in more detail how the English saltpetre refining process was ordered.

Fig 35.
Part of the pierced wall between the main block of the saltpetre refinery and the more westerly of the two southern wings. (NMR DP003519)

The 'English Process', which was in use at Waltham Abbey Gunpowder Works in the second half of the 19th century, is explained and illustrated in a handbook published in 1870 (Smith 1870, 10-21, plate 1) and subsequently repeated (Wardell 1888, 38-41, plate 1; Guttman 1895, 24-45, fig 2). The original illustration (reproduced here as Fig 36) shows a furnace with a boiling vat (A) above it (the latter with a perforated false bottom to prevent caking of the saltpetre), linked to a series of filters (B) with cloth filter bags, from which the liquor ran through a closed channel into wooden crystallising pans (C). Constant stirring of the pans with wooden rakes promoted the formation of fine crystals of saltpetre which, from time to time, were drawn up on the side and thrown on to draining shelves (D). This saltpetre was then raked into washing vats (E), 6ft (1.83m) long, 4ft (1.22m) wide and 3ft 6in (1.07m) deep, with a wooden perforated false bottom and an outlet with a plug. After three washings, all but the bottom six inches (0.15m) of saltpetre was taken out and, after three to five days' storage, with only three to five per cent moisture, it could be used for the manufacture of powder without further drying. The water from all these washings was run off into a cistern (F) below the floor for reintroduction into earlier stages of the refining cycle. This drawing and

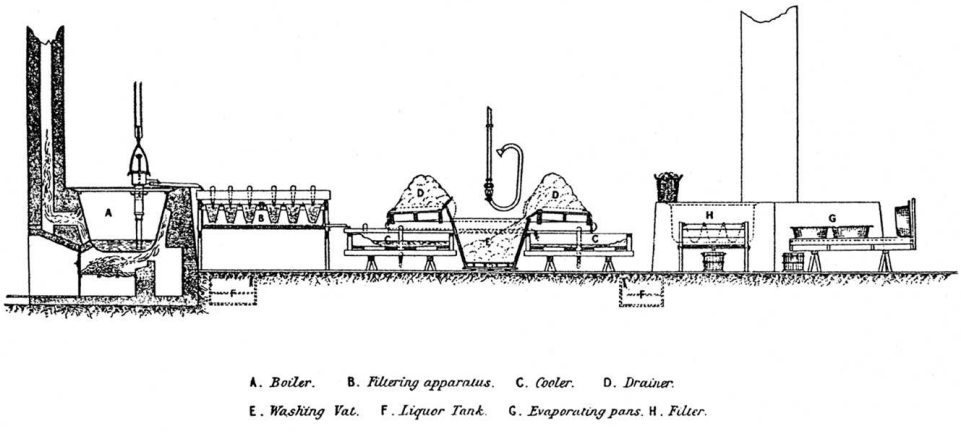


Fig 36.
The layout of apparatus used to refine saltpetre by the English process at the Royal Gunpowder Factory, Waltham Abbey (reproduced from Smith 1870, plate 1)

description can be related to the interpretation of the saltpetre refinery at Lowwood: since furnaces, boiling vats and taps for running off the boiled solution into the filters survive in the main block, the crystallising pans and washing vats must have been sited in the more westerly of the two southern wings or sheds. The principal difference between the apparatus at the two works, so far as it survives, is that whereas at Waltham Abbey the liquor in the boiling vats had to be pumped out and through the filters, at Lowwood the boiled solution could drain out under gravity.

The single-storey southern wings, separated for part of their outer lengths by a narrow blind alleyway, run south from, and pre-date, the rebuilt main block of 1849. They are built of stone rubble with reasonable quoins, and have roofs of local slate, but the doorways and windows have a mixture of stone and timber lintels of various forms and of different dates.

The more westerly of the two wings is L-shaped, and its outer wall has a shallow plinth along its full length, a feature not found on any other wall, and a variety of openings (Fig 27). The principal openings are two wide and tall doorways which are now windows (both with timber lintels with later slate hangings), a blocked doorway of more conventional size but with a voussoired segmental-arched head sited off-centre between them, a window with a stone lintel close to the main block, and a blocked doorway closer to the outer corner with a slate-hung timber lintel and brick-patched sides. The wide doorways would have enabled carts or barrows, as appropriate, to be taken into the building to service the refining process and remove any saltpetre to storage, perhaps in the warehouse block which formed the north-east wing of the 1849 rebuild. The end gable wall has a wide inserted doorway which cuts a blocked doorway on its eastern side; the later opening has a timber lintel and a sliding door. The inner wall of the wing, opening off the narrow blind alleyway between it and the adjacent more easterly wing, has a blocked doorway with a timber lintel (now a window) mid-length, and a window in the re-entrant wall defining the north-east end of the alleyway. Inside, it has already been noted that the wall between the wing and the main block has five tall, wide, round-arched openings in it to ease access between the two parts of the building. The floor of the wing would have provided ample space for several runs of the crystallising pans, drying racks and washing vats which served the later stages of saltpetre refining, and the floor of the passage to the rear of the furnaces retains drains which are likely to have received residual solution and/or washing water from the apparatus housed within the wing. The roof of the wing is supported on a series of king-post trusses, and part trusses, some with queen-posts, all with diagonal struts. The king-posts have bolted feet, the queen-posts iron straps binding foot and tie-beam.

The more easterly of the two southern wings is rectangular in shape and the series of doorways and windows, some inserted, some blocked, some with timber lintels, some with stone lintels, testify to a long life with many adaptations (Fig 27). The wing has three internal doorways, all now blocked, namely a tall round-headed opening in the passage at the rear of the furnaces and two conventional doorways from the adjacent wing. All of these doorways belong to the era of the saltpetre refinery, and relate to it as it was remodelled in 1849. What the wing was used for at this time is uncertain, however: it is poorly placed in relation to the furnaces to have accommodated either crystallising pans or washing vats,

and may instead have housed apparatus used in the recovery of additional saltpetre from the washing water, *etc* (Smith 1870, 17-20; items marked 'G' and 'H' on Fig 36). The interior is now divided into three separate parts by an inserted stone wall and a modern timber partition, each part necessarily with its own external doorway on the side facing the blind alley. The timber partition is on the line of one of five king-post trusses, the inner three more widely spaced than the rest (it may or may not be incidental that the inner three correspond to the presumed position of the old furnace stack). In 1926 the room at the outer end of the wing, divided from the rest of the wing by an inserted wall which crosses an earlier opening in the north-west wall facing the alley, was a laboratory presumably for testing the quality of the saltpetre (but see also laboratory, section 6.2.5 below, for an alternative explanation). It has a fireplace in its gable wall, the chimneystack of which projects externally and has been demolished above the line of the gable. The two windows which flank the chimneystack are both inserted, the more western one cutting a blocked doorway. The room was formerly accessible from within the wing, but this doorway is also now blocked.

The north-east wing (which is the 1849 warehouse block) is two storeys high and perfectly symmetrical (Fig 27). A longitudinal wall divides each floor into two originally separate storage rooms of near-identical size. The rooms on the ground floor have doorways and windows in the downhill end and a pair of now-blocked windows in the uphill end; those on the first floor have doorways in the uphill end, and windows in the downhill end as well as the gable wall. The paired doorways to the first floor are approached by a path which broadens out as it nears them and is supported on cast-iron columns and beams (Fig 28a and d) - the latter with decorative panelled sides (Fig 37) - which span the approach to the entrance to the blocked side door into the ground floor of the main block. The ground-floor bays of the wing, which originally had no internal opening between them (the existing opening is recent), both have modern subdivisions just within their doors; the north-east bay also has a drain in its floor which most likely relates to the post-1928 reuse of this part of the refinery as a shower room (men's washing and changing house, section 6.2.6 below).

Fig 37. View beneath the raised path to the saltpetre refinery, showing the blocked doorway and window at the end of the boilerman's passage. (Christopher Dunn, July 2005)

The 1849 clock tower is five storeys high, and its ground floor, sunk down two steps below that of the main block, has a stone vault to avoid the risk of fire caused by the nearby furnaces spreading up it (Fig 27). The ground floor can now be entered only from the main block, but it originally had a second doorway and a window, the former (now blocked) in a side wall, the latter in the uphill wall. Both these openings have round-arched heads; both are also below the present ground level on this side of the building, confirming the evidence

of the blocked window in the end wall of the vaulted boilerman's passage in the main block that there have been major changes to the ground level in this area. The side wall opposite the blocked doorway has three small segmental-arched openings in it at floor level, all blocked in stone and of unknown function (Fig 38); the arches are not visible on the other side of the wall as this is now faced with modern blockwork. The first floor of the tower is entered via a flight of steps on its uphill side leading to a doorway (again now blocked) in a round-headed opening, and has a window with a similar head in its side wall, a window whose form and position is repeated on the floor above. There is another blocked window to the north-east of the doorway. An external stone band divides the second and third floors of the tower, the latter having pairs of square-headed widows in all four sides. The wall is set back below the fourth floor - which is the clock chamber – and, as on the floor below, has pairs of windows in three walls, but a clock face in the wall overlooking the river. The form and history of the clock itself have been discussed elsewhere (Crocker and Crocker 1989). A very simple staircase rises up the tower, whose rooms have no architectural elaboration. Each of the four sides of the pyramidal roof contains a gabled, louvred vent.

Fig 38. The three blocked, arched openings in the south-west ground-floor wall of the Clock tower. (Tony Berry, June 2005)

The bridge house of the ironworks survived well into the gunpowder phase, although its use at this time is uncertain – there does not seem to have been any direct access between it and the main refinery. It was finally demolished in 1928; only part of its south-west and south-east walls survives (blast furnace, section 6.1.2 above).

Blacklead Store (building 53)

Blacklead (graphite) was needed for the process of glazing gunpowder. Several Cumbrian powder works had dedicated blacklead stores, for example Elterwater and perhaps New Sedgwick (Jecock *et al* 2003, 43; Dunn *et al* 2003, 38-9). But it is only in the 1920s in the final years of the factory's life that there is evidence for a dedicated store at Lowwood, when, according to George Shackley, building 53 fulfilled this function (information from Mike Davies-Shiel). Despite the lack of evidence, the likelihood is that building 53 had been used for this purpose since 1861, for although originally built as an expense magazine, it would necessarily have lost this function as soon as the nearby reel and glaze house was constructed (section 6.2.3 below). It may also have stored blacklead for the second glazing house (building 50) at Lowwood, for no other store building existed close to that house.

Building 53 is no longer extant, but a description of its history and form has been included in the discussion of expense magazines in section 6.2.3 below.

6.2.3 The manufacture of gunpowder

Preparing Houses

The preparing house was where the three raw ingredients of gunpowder were first brought together, ground to fine powder, and mixed in the correct ratios to produce a green or unripe charge ready for the incorporating mills. Preparing houses thus performed two separate tasks: grinding (preparation) and mixing. Indeed documents occasionally refer to preparing and mixing houses as if they were two separate buildings, but the evidence suggests that at Lowwood both processes were always carried out under the same roof, albeit in different compartments of the building. (It may be for this reason that the Lowwood example was sometimes known as the composition house). Preparing houses required access to power in order to grind and mix the ingredients, usually undertaken using small edge-runner mills and rotating drums.

For most of its life Lowwood possessed only a single preparing house, although a second (confusingly known at the time as preparing house no. 1) co-existed for a couple of decades in the second half of the 19th century. This nomenclature seems to have arisen because the original house was replaced by a wooden structure (preparing house no. 2) on the opposite side of the leat around the time house no. 1 was built. House no. 2 burned down in 1862, but was rebuilt in stone, apparently on the same site. To limit further confusion, the original names will be retained in the description that follows, and the initial building referred to as the 'earliest' preparing house. Field evidence suggests that Lowwood may have once more operated a second preparing house for a few years between *c* 1928 and 1933, converted from a pair of disused incorporating mills. However, the identification of the exact process being carried out within these two disused mills is uncertain, and detailed discussion of the evidence is reserved for later (incorporating mills 25/26, this section below).

Preparing house no. 2 survived until closure of the factory in 1935 at which time it was referred to simply as the composition house, while preparing house no. 1 was rebuilt as/ converted into a cartridge-press house in 1886 (section 6.2.4 below). The composition house is identified as building 24 on the 1926 factory plan (Fig 9), the rebuilt/converted preparing house no. 1 as building 22, which are therefore the numbers used for these buildings on the relevant phase diagrams (Figs 135-41) in this report; the two versions of house no. 2 pre- and post-1862 will here be distinguished as mark I and mark II. By 1933/4, however, preparing house no. 1 had been allocated two new numbers (26 and 27) within a revised numbering sequence, reflecting its internal division into separate compartments for grinding and mixing (MMB, 1). For the purposes of the present report, the earliest preparing house is numbered below as building 81.

'Earliest' Preparing House (building 81)

A preparing house is recorded as under construction at the works in 1799 (section 4.2 above). This is presumably the same as the 'Preparing Mill' which the 1846 map (Fig 4) shows situated between the westernmost pair of incorporating mills (nos. 25/26) and the charge house (building 23) (see also Figs 132-3). A leat approached the south-east corner of the building and ran along outside the southern wall, indicating that the house was

powered by a waterwheel located against this wall. The building was presumably demolished *c* 1859 when preparing house no. 2 was erected on the opposite side of the leat.

The site is now largely buried beneath the massive embankment retaining the re-routed headrace to the modern hydro-electricity station, and no surface trace of either the house or its leat was found during the EH survey.

Preparing House no. 1 (building 22)

The earliest evidence for 'Preparing House no. 1' is the 1863 sale plan (Fig 6), which depicts it as an almost square building close to the river bank opposite Ford Island. Its exact date of construction is not known, but it cannot have been built before 1846 (compare Fig 4) and presumably existed by 1859 which is the likely date of preparing house no. 2's construction. The sale plan suggests that power came from a waterwheel external to the south-western wall. The building was rebuilt or remodelled in 1886 to convert it into a cartridge-press house (section 6.2.4 below).

The only structural evidence which EH found for this building during field investigation was a wall probably representing the southern side of the tailrace (Fig 142), but the site is now so thickly overgrown that any slight traces may easily have been overlooked.

Preparing House no. 2 (building 24)

The earliest specific reference to 'Preparing Ho[use] no. 2' is, once again, the 1863 sale plan (Fig 6). Preserved in the HF archive (LW/1850/017 and 18), however, is a tender from a certain Charles Blades in reply to a specification for the erection of a 'Timber crushing house'; both documents are dated 26 November 1859, and are presumably referring to a preparing house to be pre-fabricated out of wood. The intended building was to measure 43 feet 6 inches by 28 feet by 10 feet high to the eaves (13.26m by 8.53m by 3.05m). Circumstantial evidence points to it being this building which burned down on the night of 2 March 1862 (section 4.2 above), for a contemporary newspaper report of the incident states that the preparing house - which was the seat of the fire - stood close to a pair of incorporating mills which were also destroyed. Whilst the building in question could have occupied the same site as the earliest preparing house, it is more likely to have stood on the opposite side of the leat which is the position the 1863 sale plan records for its replacement structure. According to information on the 1926 factory plan (Fig 9), this mark II version of preparing house no. 2 was constructed in stone.

The first edition OS 25-inch map (Fig 7) shows that, by 1888, the mark II building was served by a number of tram lines. One, which approached from the direction of the saltpetre refinery, terminated alongside an apparent covered loading-bay against the south-eastern wall, and must have been the route by which raw materials were brought from their respective stores (section 6.2.2 above); a second originated from beneath another covered loading-bay external to the south-west gable wall, and led straight past the charge house, building 23. Extra detail visible on the 1926 factory plan suggests that the southern end of the building was also screened by a blast wall, while the roof of the south-eastern loading-bay may have been removed by this time.

The evidence of the MMB (pages 1-4) shows that, at least by 1933/4, the building was divided into two 'compartments' internally. In one, charcoal and sulphur were ground under an iron edge-runner mill: charcoal in the mornings and sulphur in the afternoons. The pulverised cake was fed into a hopper feeding rotating 'inclined open-ended cylindrical sieves or reels', one for charcoal and one for sulphur. Each reel was 2 feet (0.61m) in diameter, 6½ feet (1.98m) long, and lined with fine copper mesh of 24-apertures-per-linear-inch gauge. Material which passed through the mesh emptied into bins which extended into the second compartment, while oversize particles ('stops') were returned to the mill. Meanwhile, in the second compartment saltpetre was agitated through a flat sieve of 8-apertures-per-linear-inch gauge, and weighed into a tub. Charcoal and sulphur from the bins were weighed out and added to the tub. The resultant 'charge' was up-ended into the mixing drum and run at high speed for two minutes before being emptied into another tub and taken away to the charge house. By this date Lowwood was producing charges weighing 75lb (34.05kg) each. (For discussion of the increase in the size of charges over time, see incorporating mills 27-38, this section below). Three men were capable of grinding and mixing 110 charges per day.

There is now no trace of preparing house no. 2, which lies beneath the course of the re-routed leat to the modern hydro-electricity station.

Green-Charge House (building 23)

Although not a specific legal requirement before 1860, charge houses for the storage of green or unripe charge were an inevitable consequence of the 1772 Gunpowder Act which placed limits on the amount of powder which could be present within process buildings at any one time; because of these limits, after 1772 all gunpowder works needed to provide expense magazines or similar for the temporary storage of powder as it progressed between the various stages of manufacture. The Act stipulated that such temporary magazines and storehouses had to be built in brick or stone, and could not be erected closer than 50 yards (45.7m) to any mill building (Cocroft 2000, 28). However, green charge fresh from the preparing house was considerably less explosive than ripe charge (the name given to powder which had passed through the incorporating mills) and seems to have been considered exempt from these legal controls. The loophole was partly addressed by a later Act passed in 1860 which made charge houses a legal requirement; but the Act still failed to set a minimum safe distance, merely stipulating that such houses must be 'a safe and suitable Distance from each Incorporating Mill or Group of Incorporating Mills' (Public Statutes General 1860, 616).

Lowwood would therefore have possessed a charge house or similar building right from the start of business in 1799, but the earliest explicit reference to the existence of such a building is not until almost 50 years later when the 1846 plan (Fig 4) depicts a 'Charge House' immediately north-west of the contemporary 'Preparing Mill' ('earliest' preparing house, this section above). As the depicted building is only some 30m from the nearest incorporating mill it must have been for the storage of green charge only. For a couple of decades early in the second half of the 19th century, the charge house also had to accommodate the output of a second preparing mill (preparing house no. 1, this section above) sited close to the river bank some 25m to the west, but there is no evidence that it was enlarged as a result. Indeed, the charge house remained in use - seemingly unaltered - until

closure of the works in 1935, for a rectangular structure of the same basic footprint appears on all subsequent map depictions, including the 1926 factory plan (Fig 9). According to the OS first edition 25-inch map (Fig 7), by 1888 it was linked to the then single preparing house by a tram line which ran adjacent to the south-east wall, beyond which a blast wall (here called BW6) had been erected to provide protection to/from the incorporating mills. The second edition map (Fig 8) shows that by 1911 a blast bank (here called BB6) had also been added behind the building to shield it from the cartridge-press house converted from preparing house no. 1 in 1886 (section 6.2.4 below). The 1926 factory plan portrays the green-charge house as a stone construction: it also identifies it as building 23, which is therefore the number used for it on all relevant phase diagrams (Figs 132-41) in the present report.

The green-charge house is no longer extant. It was presumably set alight at closure because of the danger of gunpowder residues, and the ruins demolished after 1939 to make way for a wartime Nissen hut whose concrete base still occupies the site (section 6.3.1 below). Blast wall BW6 which shielded the front of the building has likewise disappeared, but blast bank BB6 to the rear survives as an overgrown earthwork supporting mature trees and scrub vegetation. In the south this bank stands to seemingly its full original height of *c* 1.5m, but the northern third is much reduced.

Incorporating Mills (buildings 25-38)

Once mixed, green charges had to be incorporated (incorporation was also sometimes called amalgamation). This process was designed to ensure that the powder was thoroughly combined and of the correct density. A little water was normally added at this stage to make the charge hold together better; this also had the effect of dissolving some of the saltpetre which aided its absorption by the charcoal.

Incorporation was carried out using a particular form of edge-runner mill. Early designs consisted of a large bedstone and two vertical rollers or edge-runners, all manufactured out of limestone; the green charge was placed on top of the bedstone - around the edge of which a deep, angled, retaining curb was fitted - and mixed by the edge-runners which turned and rotated in the ‘pan’ so formed. Turning motion was imparted via a vertical spindle (which could be powered either from above or below: termed over-drive and under-drive), but rotational movement relied on friction between the edge-runners and charge laid within the pan. A later, safety modification entailed suspending the edge-runners about 6-9mm above the pan to eliminate frictional heat which could be generated if they momentarily came into contact with, and skidded on, the pan surface (*ie* the bedstone) itself. Another (relatively late) design innovation involved the substitution of hollowed iron wheels and a totally iron bed plate in place of the limestone traditionally used (Patterson 1986, 15-24).

In common use, the phrase incorporating mill can refer to either the edge-runner mill or the building in which the process was accommodated. To avoid possible confusion, the present report will always use the term to mean the mill building, with the machinery referred to as an edge-runner mill.

In 1799 when Lowwood opened, it had only one incorporating mill - or at most a pair of mills - in operation; by 1803, the number had increased to three, whilst between 1828 and 1846 a further eleven were constructed bringing the total number to fourteen (section 4.2 above). All were water-powered, over-driven, and after 1828 arranged in pairs (*ie* a mill chamber situated either side of a central wheel-pit), although before then one (it is not recorded which) must have existed as a singleton. The seven pairs were laid out in an approximate oval close to the southern end of the headrace. The 1926 factory plan (Fig 9) identifies the fourteen mill buildings as numbers 25-38, with the numbering starting with the westernmost pair and proceeding round the oval in an anti-clockwise manner. There is no documentary evidence for the order in which the mills were constructed, but pairings 33/34, 35/36 and 37/38 shared a leat which branched into three and may well have been constructed as a single development, while nos. 25/26 were probably the earliest as they were both of a substantially different design to the other twelve. In this pair, the rear and sides to the chambers were formed by high stone walls, with access in each case obtained via the fourth side which had a wooden frontage; the edge-runner mills within may initially have been powered via pitwheels or flywheels driven directly from the waterwheel axle (Fig 41b), but by 1887 power came from a single horizontal driveshaft carried through both inner walls adjacent to the wheel-pit, driven by ring gearing (Fig 41c). In contrast, the other six pairs seem to have been two-storey structures consisting of stone part-basements either side of the waterwheel, capped by wooden sheds; the basements contained flywheels, while the timber superstructure housed the edge-runner machinery sited at ground level on the lip of the basements. In this design of mill, power was transmitted from the central waterwheel up, across and back down to the central vertical spindle of the edge-runner mills via bevel and crown wheels turned by the flywheels in the basements which were driven directly from the main waterwheel axle (Fig 43), similar to the putative phase 1 arrangement in mills 25/26.

However, in 1928 the five easternmost pairs (nos. 27/28 - 35/36) were modernised: one mill chamber in each pair was demolished, and the other rebuilt entirely in stone to accommodate a new design of under-driven, metal, suspended edge-runner mill; the machinery supposedly arrived at Lowwood second-hand, having previously been in use at the Fernilee Gunpowder Works in Derbyshire (section 4.2 above). The installation of these suspended edge-runner mills required the creation of a new two-storey structure, with the drive mechanism housed at basement level but with the mill machinery now located directly above; power was transmitted to the edge-runners through the bedplate (Fig 52). Of the remaining two pairs, nos. 37/38 continued in use in an unconverted form, but the machinery in nos. 25/26 was dismantled and the mill chambers converted to alternative use. By 1933/4 the seven surviving mills had been re-numbered as buildings 33-39 (MMB, 5), but it is the earlier numbering sequence which will here be used to refer to all phases - both in the description below and on the phase diagrams (Figs 132-41) at the end of this report – with pre- and post-1928 versions distinguished by use of the suffixes mark I and II. This numbering scheme had been in use for at least 60 years by 1926, for mills 29 and 37 are both mentioned in 1866 (HF LW/958/267 and 571). The scheme appears then to have been a recent introduction, however, since a different numbering sequence is recorded in 1863. At that earlier time, the mills were numbered in pairs rather than individually; full details have not survived, but mills 25/26 and 37/38 seem to have been known as buildings 13 and 14 (HF LW/1863/005).

Incorporating mills were prone to blow up and a series of explosions are recorded at Lowwood, although mostly without fatalities (mill keepers retired to the safety of the watch house once the edge-runner mills were set in motion) or serious damage to the machinery and buildings. The wooden parts of the superstructure were actually intended as a safety valve, designed to blow off in the event of an accidental explosion so that the blast would dissipate quickly minimising damage to the expensive machinery within; stone blast walls – which in the case of mills 25/26 and the mark II versions of mills 28, 30, 32, 34 and 35, were integral with the structure, but in the mark I design of mill pairs 27/28-35/36 were freestanding – then directed the force of the explosion upwards rather than sideways. One man was injured in 1856, however, and two killed in 1887 in a flash fire while carrying out maintenance in mills 25/26. The wooden parts of mills 25/26 also burned down in 1862, although the fire originated in the adjacent preparing house, not the mills themselves (section 4.2 above and appendix 1 below).

Sometime after the works closed in 1935, a turbine and electricity generator were installed in the former basement to incorporating mill 36 which was one of those demolished in 1928. A turbine (manufactured by the firm of J J Armfield) and generator are still *in situ* within the basement, but both would appear to be secondary. According to Tyler (2000, 139), the extant turbine/generator combination was used until recently to power a small portable saw-bench, but the units they replaced are likely to have been installed originally to generate the 110v DC power supply to Birk Dault and the houses in Low Wood prior to those buildings' attachment to the National Grid in 1953 (information from Oliver Barratt). There is no evidence that a turbine was ever used to power the edge-runner mill in incorporating mill 35 mark II on the other side of the waterwheel-pit.

Incorporating mills 25/26

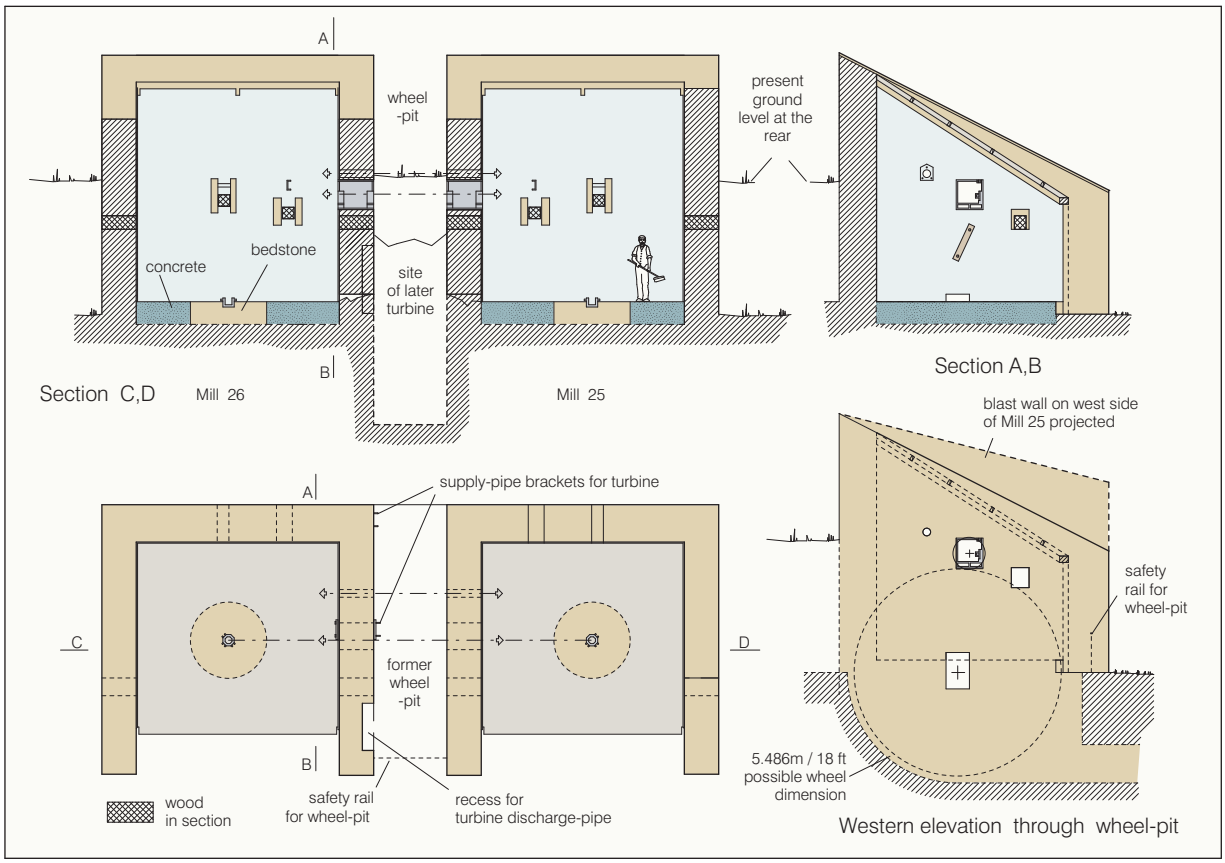
The twin chambers of the earliest pair of incorporating mills at Lowwood, nos. 25/26, face slightly east of north, and stand parallel to each other either side of a central waterwheel-pit (Fig 39). Each chamber is rectangular in plan, 5.3m wide by 6.1m deep, and thickly walled on three sides with roughly-coursed, stone rubble masonry, 0.91m thick so as to contain the force of any accidental explosion (Fig 41a). The walls all stand to their full height and mostly retain their original stone copings, but much of the exterior of both rear walls, and part of that of the two outer side walls, is now obscured by a massive embankment created in the 1960s to retain the heightened headrace to the hydro-electricity station; the north-east side of this embankment has also spilled into and infilled much of the wheel-pit. Ivy and sapling trees have taken root in the upper levels of the walls (Fig 40), and although this vegetation was cut back immediately prior to investigation in the winter/spring of 2004, not all the roots could be severed with the result that some stools have already

Fig 39. Incorporating mills 25/26 viewed from the north-west following clearance of vegetation from the fabric. Note the higher walling on the west side of mill 25. (NMR DP003470)

(summer 2005) started to re-sprout. Three of the four side walls slope steeply down from rear to front, the exception being the west wall of incorporating mill 25 which has a flatter top in order to provide additional blast protection for preparing house no. 2 and the charge house which lay beyond. The western corner of the same chamber is particularly well-formed of dressed-stone quoins but the other corner has much smaller and less regular quoins, while the ends of the side walls and the corners and ends of incorporating mill 26 are mostly unquoined. The reasons for these structural differences are unclear, but the differences may be indicative of the two mills having been built or partly reconstructed at different times. The inner wall faces of both chambers are thickly, but smoothly, cement-rendered in order to exclude ledges or irregularities where dangerous gunpowder dust might have collected. It is clear that the walls of each chamber rose above the level of the single-pitch roofs and that the side walls also projected beyond the fronts because the rafter lines, remains of lead flashing, and front wall-plate positions are clearly visible in the rear and side walls of both mills beneath upper areas of unrendered masonry (Fig 40). The roofs and fronts are now lost, but the accident report by Major Cundill necessitated by the death of two maintenance workers following a flash fire in 1887, describes the roofs as 'pent shaped, of light boarding' and 'the greater part of the wooden fronts [as] taken up by large folding-doors' (Explosives Inspectorate 1887, 3-4). Cundill also reported that the chambers then had wooden floors; these must have been replaced in 1928 by the surviving concrete versions (see below). The accident report makes no mention of the incorporating mills being fitted with drenchers (50-gallon (227.3-litre) tanks of water balanced on a common shaft above the edge-runner mills, designed to empty onto the charge and extinguish the flames if one mill in a pair blew up, at the same time as dampening the charge in the adjoining mill to prevent the explosion communicating to it (Patterson 1986, 20)); however, these may have been fitted later as the MMB (page 5) states that drenchers did exist within the neighbouring pair of incorporating mills nos. 37/38 in 1933/4.

Fig 40. Incorporating mill 26 from the east before clearance of vegetation from the fabric. (NMR DP003433)

Each incorporating mill contained a single edge-runner mill. These were powered by the waterwheel whose axle was originally level with each chamber's wooden floor and turned in bearings contained in openings in the inner walls, although these openings are now largely masked on the chamber side of the wall by the later concrete floors and on the wheel-pit side by the modern embankment (Figs 40 and 41a). The presence of two large cast-iron wall boxes high up in the inner walls indicates that, in the mills' final form, power was taken off the waterwheel by a spur wheel and transmitted to the edge-runner mills by a single horizontal drive shaft. The box in the wall of mill 26 has a pair of rings cast into it (possibly to mount a lever) plus a bracket on the inside, which may have been part of a clutch mechanism for lifting the drive shaft from the wheel and so stopping the edge-runner mills.



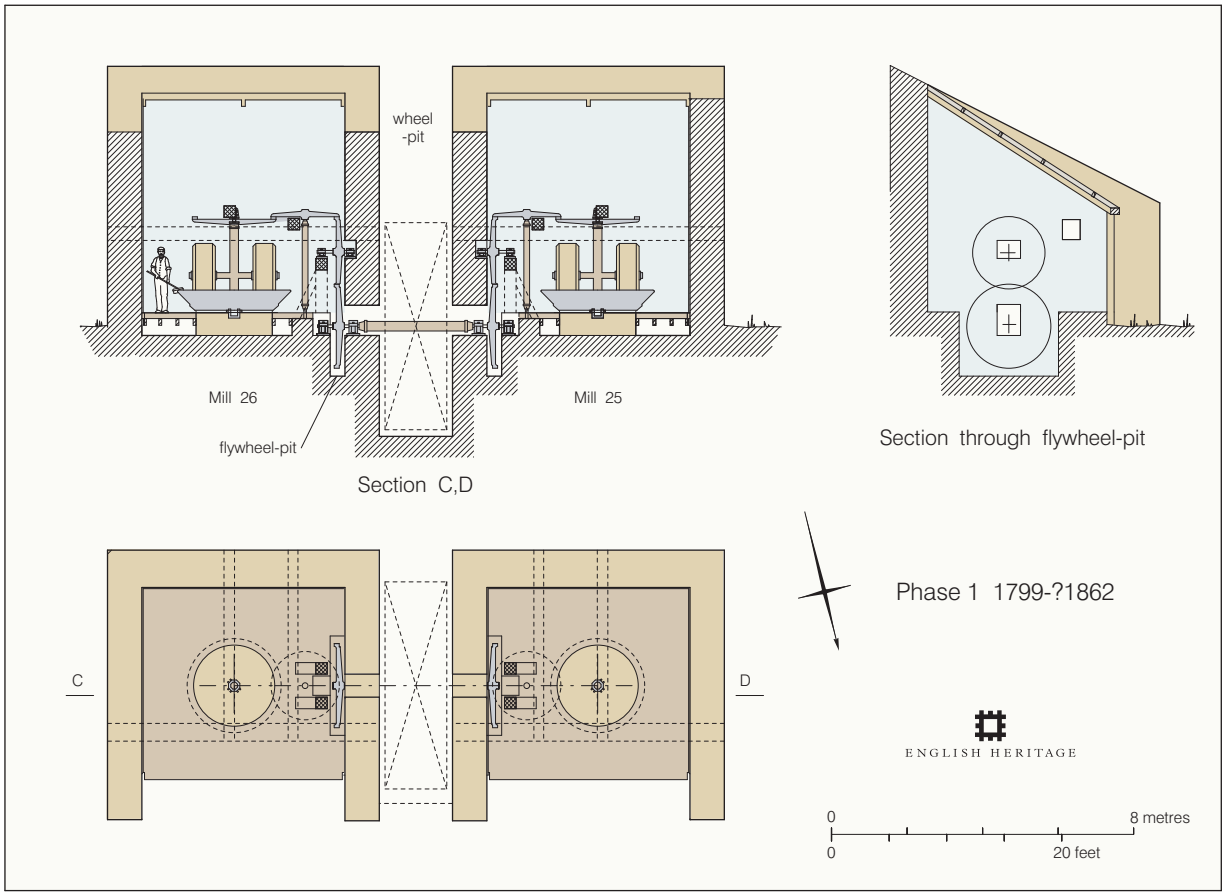
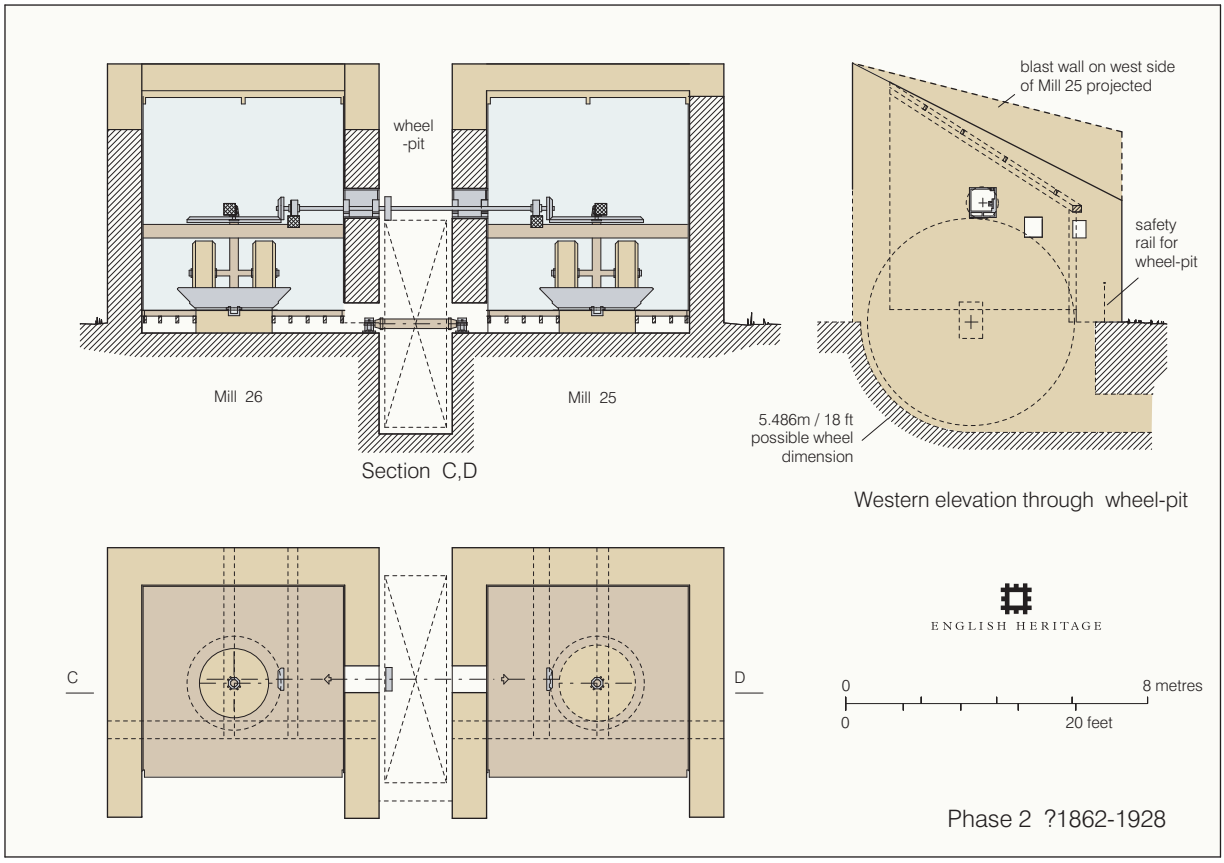


Fig 41a (top). EH plan and sections of incorporating mills 25/26 (see page xiv for key to conventions).
Fig 41b (bottom). Suggested layout of incorporating mills 25/26 between 1799 and 1862.



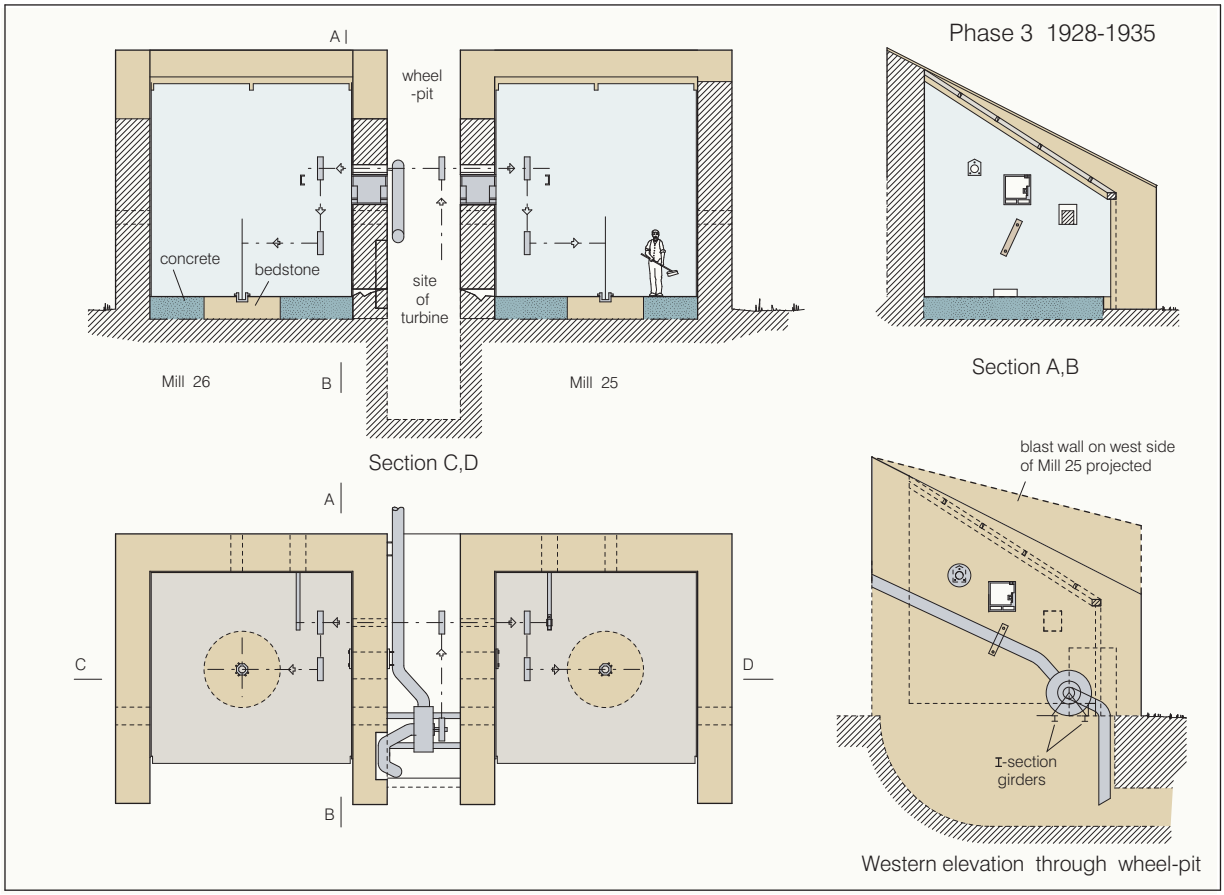


Fig 41c (top). Suggested layout of incorporating mills 25/26 between 1862 and 1928.
Fig 41d (bottom). Suggested layout of incorporating mills 25/26 between 1928 and 1935.

Each end of the drive shaft terminated in a bevel pinion which turned a large crown wheel set upon the central edge-runner mill spindle (Explosives Inspectorate 1887, 4). The axles of two large limestone edge-runners were attached to the spindle and turned on the bedstone which was fitted with a central cast-iron socket in which the spindle itself turned; bedstone and socket are still apparent in each chamber (see below). Above, three timber beams set in the side and rear walls braced and supported the edge-runner mills and their driving apparatus: the main supporting beam was set into the side walls (in rectangular openings, with lintels, which have been partially blocked up), towards the front of the chamber and a little below head height. A second beam, set slightly higher, was bedded in the rear wall and ran at right angles to the main beam into which it was jointed. Set off-centre, this beam supported the drive shaft from the wheel, possibly in an open bearing block. A further timber beam, also bedded in the rear wall and at right angles to the main beam to which it was joined, was set a little higher and roughly above the centre of the edge-runner mill (forming, as Cundill described in his report, a T-shape with the main beam). The purpose of this beam was to brace and fix the top of the central edge-runner mill spindle. A reconstruction of this gearing and support mechanism is reproduced at Fig 41c.

This is unlikely to be the original gearing arrangement, however, since ring gearing was not used in England before *c* 1810 (information from Dr Pat Strange and Alan Stoyel). It may well be, therefore, that drive was initially taken off the waterwheel axle via a flywheel in each chamber, but such a suggestion can at present only be hypothetical since any evidence for flywheel-pits has been obscured by the concrete floors inserted in 1928. A possible reconstruction of the putative initial gearing arrangement - based on a late 18th-century drawing of the inside of an incorporating mill at Faversham (Palmer 1998, 9 fig 5) - is illustrated in Fig 41b. The Lowwood partners are known to have been in correspondence with a certain Mr J Stevens at the Faversham gunpowder works (Palmer 1998, 2): the Faversham mills may well have been the inspiration for Lowwood's initial design of mill, therefore. The gearing arrangement possibly lasted as late as 1862 when it is known that the timber parts of the two mills were destroyed by fire.

In 1928 ICI converted incorporating mills 25/26 to some new but unknown process. A reconstruction of this final phase of the buildings' use is illustrated in Fig 41d. The waterwheel was removed as were the drive shaft, gears and all the edge-runner machinery except the bedstones which were probably too heavy easily to be removed; certainly the stone edge-runners were not moved further than needed, and were merely dumped in front of each chamber where they remain to the present day (Figs 39 and 40). The wooden floors were replaced with concrete ones flush with the surface of the retained bedstones – hence almost completely obscuring the openings for the waterwheel axle-bearings - and a water turbine (since removed) installed in the wheel-pit. That the supply pipe to this turbine was secured on the east side of the pit is evidenced by the remains of two brackets which survive in the wall at different levels: the higher bracket was simply held by bolts secured into the wall, but the lower one was attached to a timber mounting fixed to the chamber wall by two bolts passing right through the wall and secured by a retaining plate on the far side. There is no evidence for how the turbine itself was supported within the wheel-pit, but

comparison with what is visible at both the glazing house and sawmill where turbines were also installed within the pit (this section and section 6.2.6 below) suggests it would have been carried on two parallel iron girders. A rectangular recess with an I-section lintel was created in the face of the eastern wall of the pit to accommodate the curve of the turbine's discharge pipe. This latter work seems to have involved the partial rebuilding of the lower part of the wall, which was finished with large regular quoins; fresher cement on the inner face indicates the extent of the interference. The remains of bolts near the ends of the inner faces of both side walls indicate that the wheel-pit was protected by a safety rail at this time, as it presumably had been in previous phases too. Power from the turbine was transmitted by belt drive to a new shaft, set further back and higher than its predecessor, which passed into the former incorporating-mill chambers through ribbed cement-lined holes (presumably originally fitted with bearings); the shaft was further supported by angle irons projecting from the rear walls of each mill, the stubs of which are still visible above the lines of the earlier timber beams.

It is not known what process the converted mill chambers housed, but it was evidently not one which would have resulted in the structures being classified as 'danger buildings', or else when the works closed they should have been set alight so as to be cleansed of powder residues: the absence of charring on surviving timberwork, of any sign of smoke blackening on the stonework, and the survival of remnants of lead roof-flashing (which would have melted in a blaze), indicates clearly that this did not happen (although one might perhaps have expected the mills to have been fired in 1928 anyway if they were downgraded into non-danger buildings at that time). The structures may have been converted to provide additional preparing capacity, but this is perhaps unlikely given that the MMB makes no mention of a second preparing house in 1933/4. The most probable reuse is to house dynamos for electricity generation, but without documentary evidence this can be no more than conjecture.

Incorporating mills 27-38

The other twelve incorporating mills (nos. 27-38) at Lowwood mostly originated between 1828 and 1846. Five were demolished and five remodelled in 1928, but in their pre-1928 (*ie* mark I) form, they were similar to nos. 25/26 in that they were arranged in pairs with each pair powered by a central waterwheel. However, the superstructure of the six pairs differed markedly from nos. 25/26 in being constructed entirely in timber, not stone: this is demonstrated clearly by the nature of their depiction on the 1926 factory plan (Fig 9) and by a photograph of two of the mills before conversion (Imperial Chemical Industries 1929, 341 top, reproduced here as Fig 42). The modernisation and/or demolition of ten of the mills in 1928 has destroyed or obscured much of the physical evidence, but a conjectural plan

Fig 42.
One of the pairs of mark I incorporating mills pre-dating 1928, probably mills 37/38. (Reproduced from Imperial Chemical Industries 1929, 341)

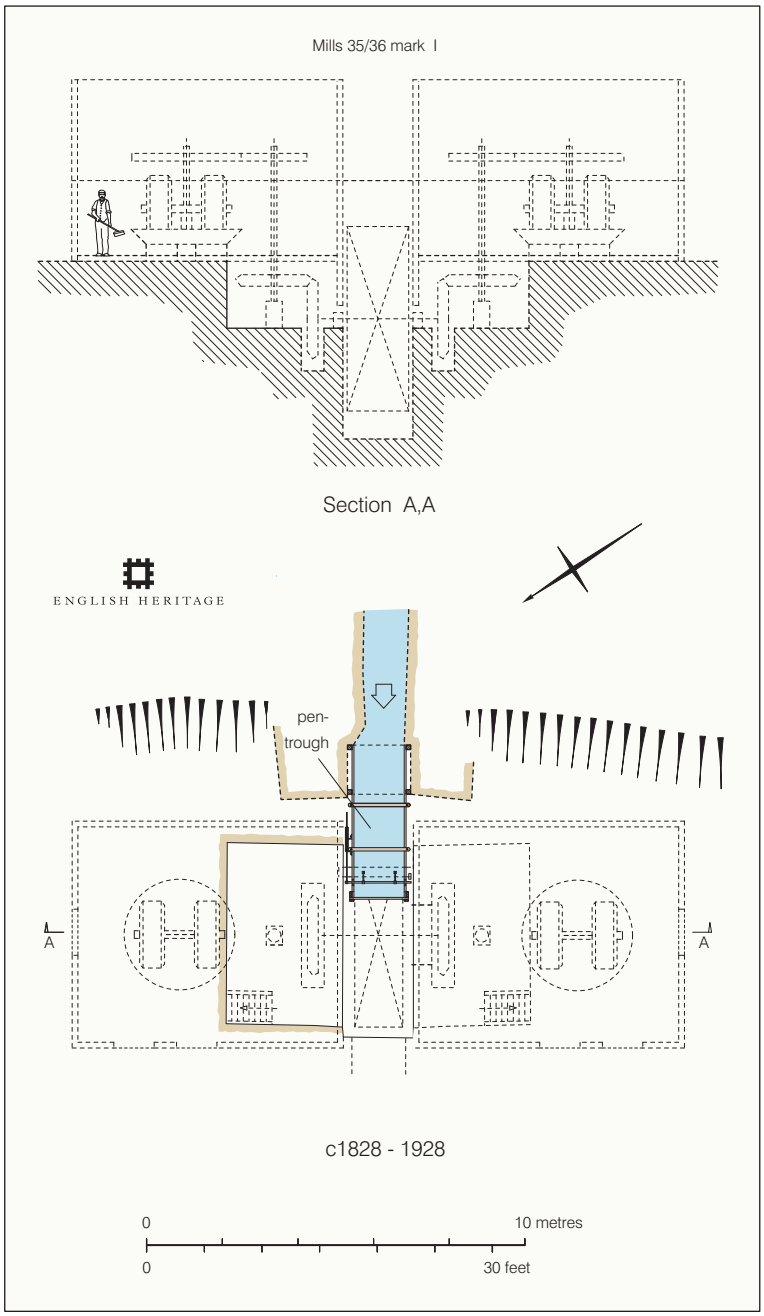


Fig 43.
EH conjectural plan and section of incorporating mills 35/36 mark I (see page xiv for key to conventions).

and long section of the most likely form and layout is reproduced here at Fig 43. This is based on mills 35/36 where the waterwheel-pit and exposed basement level of the original mill 36 have been exposed through later use as a turbine house, but also draws on a number of other sources, namely: evidence from the ruins of the surviving unconverted pair, nos. 37/38; the photograph of the timber super-structure; and finally comparison with apparently similar designs of mill at the Elterwater gunpowder works (Jecock *et al* 2003, 48-64).

The only parts of the original structures seemingly retained in the five mill pairings affected by the 1928 modernisation were the waterwheel-pits, but with the exception of that between mills 35 and 36 these are all now infilled; the pit between the unconverted mills 37/38 is also largely obscured by débris. If the visible evidence can be extrapolated to all the twelve mark I mills, however, it suggests that the pits were stone-lined and that water exited through a culvert with a stone-voussoired segmental entrance arch. The remains of wooden pentroughs survive *in situ* above the wheel-pits at two of the converted mills but as these are most likely to date from the modernisation, description of their form is accordingly reserved for discussion of the mark II mills below. The leat supplying water to the wheel between mills 37 and 38 must have been elevated to carry it across the track leading to nos. 35/36, and its embanked course survives immediately south of mill 35. The field evidence indicates that in its final form this leat was stone-lined and 3.69m wide, but as all available historical mapping depicts

it as narrower it is possible that it was widened after 1926 – most probably in 1928 as part of the general improvements to the factory - perhaps to act as a small mill pond.

Incorporating mills 37/38 are now largely ruinous (Fig 142): the whole of the northern chamber (no. 37) and much of the southern (no. 38) is obscured by tumbled stonework, fallen trees and other vegetation. However, the evidence from the more visible southern chamber which exhibits a stone-lined part-basement immediately adjacent to the wheel-pit, with a raised platform area beyond (Fig 44), and from the exposed basement of the decommissioned mill 36 (Fig 45), shows that the wheel axle must have turned bevel-geared flywheels at basement level (Fig 43). Each basement presumably also contained a horizontal gear wheel on an upright spindle which connected with the flywheel, and transmitted power up through the floor of the incorporating mill to a crown wheel on top of the spindle which then turned a further crown wheel attached to the edge-runner mill spindle, very similar to the design of mills at Elterwater (Jecock *et al* 2003, 49). The edge-runner mills themselves do not survive apart from the bedstones to mills 37/38 which both lie discarded, *ex situ*, in front of the chambers: each has a square central socket, 0.38m across, set within a circular recess 0.52m in diameter, which originally housed the iron spindle bearings. The original site of the bedstone within mill 38 is indicated by a curving scarp in the edge of the platform immediately above the rear lip of the basement (Fig 142).

Fig 44.
Incorporating mill 38 viewed from the north-west. The more ruinous wall at left of frame marks the rear edge of the waterwheel-pit, the stub wall next to it the division between wheel-pit and part-basement. (NMR DP003436)

Fig 45.
The exposed part-basement of incorporating mill 36 mark I, containing the later Armfield turbine. Note the patching in the rear wall showing that the supply pipe has been inserted into an existing structure. (NMR DP003472)

Unlike incorporating mills 25/26, the mark I design of mills 27-38 did not incorporate stone walls as part of the structure. Instead each edge-runner mill was protected from the elements by a simple wooden shed. The sheds at Lowwood are known from photographic evidence (Fig 42) to have been rectangular in plan, steeply-gabled and weather-boarded, evidently with a single rectangular window in the outer end wall and offset paired doorways in the front elevation; one of the latter presumably opened onto a flight of timber steps leading down into the basement, while the other gave access to the edge-runner machinery situated on the platform (Fig 43). These sheds were designed to disintegrate readily in the event of an explosion with each pair of incorporating mills shielded from its neighbour(s) by trees or by a detached blast wall: two such walls are depicted on the 1863 sale plan between mills 29/30, 31/32 and 33/34, but appear to

have been recently constructed for the 1846 plan shows trees rather than walls (compare Figs 4 and 6). By 1888 blast walls also existed between pairs 27/28 and 29/30, 33/34 and 35/36, and 35/36 and 37/38 (Fig 7); the last of these was placed adjacent to mills 37/38 but was angled in the middle so as to shield that pair from both nos. 25/26 to the south and 35/36 to the east. It is tempting to equate the construction of these later blast walls with dispensations granted by HM Explosives Inspectorate to a selected few factories between 1882 and 1886 to incorporate larger charges (the limit was raised from 60lb (27.24kg) to 80lb (36.32kg)) provided that the mills were separated by stone walls at least 2 feet (0.61m) thick and fitted with drenchers (Patterson 1986, 20). For the purposes of the present report, the five blast walls will be numbered BW1-BW5, starting in the south and proceeding in an anti-clockwise direction. Only the last of these, BW5, shielding mills 37/38, is extant, however, and that ruinous and overgrown (Fig 46). It is best preserved at its western end which faces south towards mills 25/26 where it measures 0.9m thick and stands over 3m high, its southern side retained by a sloping buttress positioned centrally. A short stretch of the wall's northern end also survives as a low overgrown mound some 0.5m high. The missing central part of the wall must have been pierced by the leat to mills 37/38. It is likely that BW1-BW4 were all demolished at modernisation in 1928 as the back and sides of the mark II chambers were built in stone 0.63m thick, thus meeting the Inspectorate's conditions for incorporating larger charges and obviating the need for free-standing blast walls between the modernised mills. By this date Lowwood appears to have been authorised to incorporate 150lb (68.1kg) of green charge at a time, made up of two 75lb charges (Patterson 1986, 20-1; MMB, 6).

Fig 46. The west end of blast wall BW5, viewed from the south. (NMR DP003435)

As already noted, modernisation of the five pairs of incorporating mills 27/28 to 35/36 involved the demolition of one mill chamber in each pair and the rebuilding of the other to accommodate a more modern design of edge-runner machinery. Of the five rebuilt, mark II, chambers, four (nos. 28, 32, 34 and 35) are still extant in various states of preservation: nos. 34 and 35 (Figs 47 and 48) are both well-preserved, but the lower basement levels to nos. 28 and 32 have been buried beneath part of the embankment constructed in the 1960s to retain the heightened headrace to the hydro-electricity station, and the superstructure of mill 32 is in an advanced state of collapse. All have lost their roofs, fronts, machinery and waterwheels, although two preserve elements of

Fig 47. Incorporating mill 34 mark II, viewed from the west. (NMR DP003438)

pentroughs. There is now no surface trace of the fifth mark II incorporating mill (no. 30) which is known only from a photograph (Fig 49), apparently taken in June 1929 during conversion. This photograph is doubly useful as it also provides a record of the design of the mills' lost frontages: a light-weight timber-framed screen made up of a central grid of thirty rectangular lights, six wide by five tall, above a solid lower panel. Access into the mill was via doorways at either end of the screen. Furthermore, the photograph indicates that the reconstructed mills were supplied with electric lighting from power cables fixed to overhead wooden rails attached to poles; the lights were positioned externally, but were intended to light the interior by shining in through the windows. Although not immediately apparent in the photograph, it is probable that some of the poles also supported earthing catenaries as protection against lightning strikes; a similar system is certainly recorded in connection with the cartridge-press house at this time (section 6.2.4 below).

Fig 48.
Incorporating mill 35 mark II, viewed from the north-west.
(NMR DP003442)

Fig 49.
Incorporating mill 30 mark II, viewed from the west in 1929.
(Patterson Collection, ©English Heritage.NMR)

Each of the new incorporating mills was powered by its own waterwheel, in pits which appear to have been retained from the mark I design. No change to the method of motive power appears to have been made before the works closed in 1935, since the MMB (page 5) records that each of the mark II mills was still driven by a waterwheel in 1933/4. The flow of water to the wheel was tightly controlled by a sluice housed in a timber pentrough, and the axle of the waterwheel functioned as the primary drive shaft. Decayed pentroughs survive adjacent to incorporating mills 28 (Fig 50a) and 34; their form can be largely reconstructed (Fig 51) with the aid of a photograph taken in 1968 (Fig 50b): it seems likely that the lever controlled a vertical rod which raised and lowered a wooden plug or hinged flap in the floor of the trough.

Fig 50.
Two views of the pentrough to incorporating mill 28 mark II:
a (left) in 2004.
(NMR DP003434)
b (right) in 1968.
(Davies-Shiel Collection, copyright reserved)

The basements which had formerly occupied only part of the under-floor area were extended beneath all of it to enable the transmission of power by bevel gearing and vertical shaft into the centre of the suspended-runner mill chamber. Service access to each basement was through the side wall away from the wheel-pit via an external concrete staircase covered by a simple lean-to structure. The suspended-runner mill chambers were themselves rebuilt with blast-proof stone-rubble sides and backs.

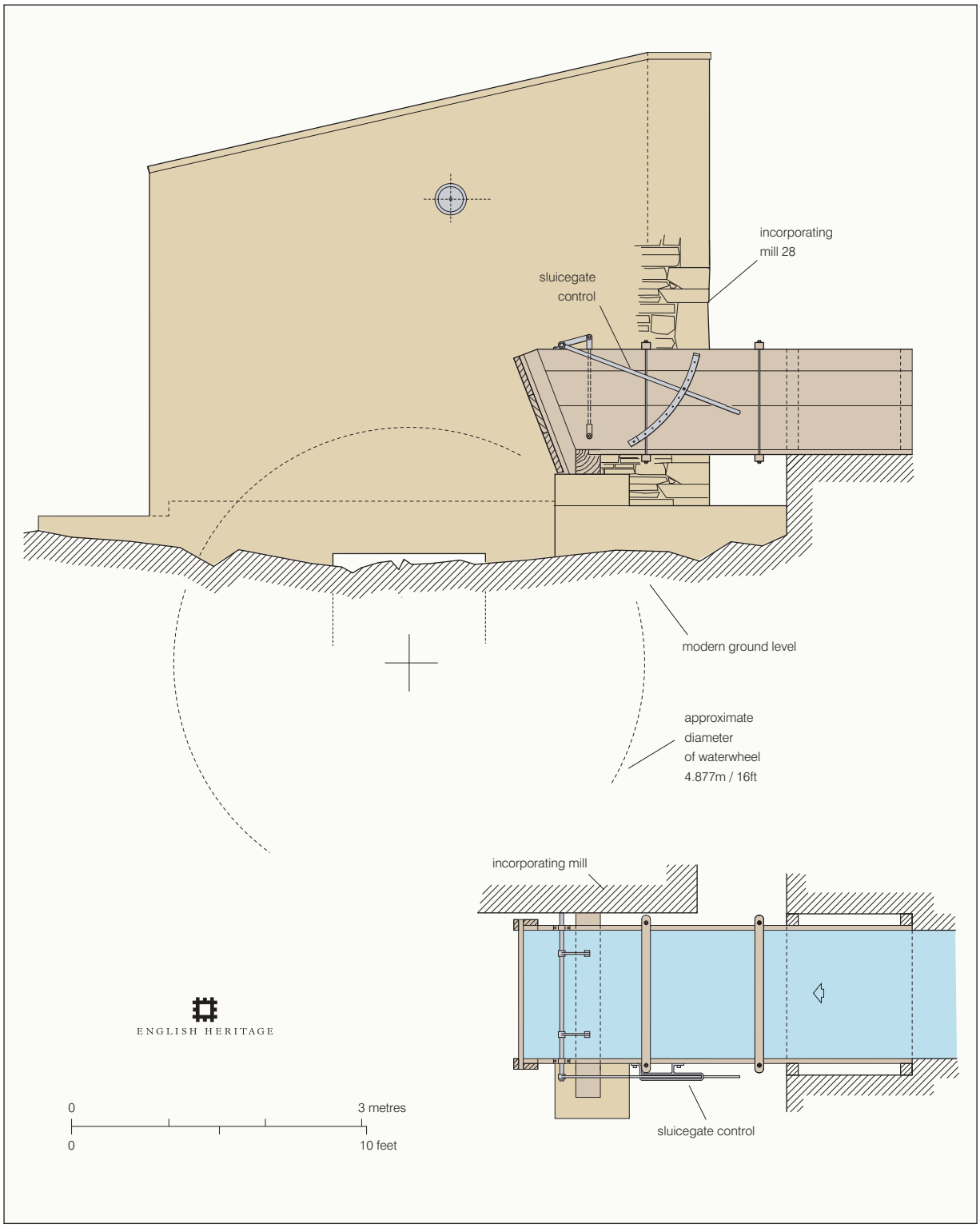


Fig 51. EH reconstruction drawing of the decayed pentrough above incorporating mill 28 mark II
(see page xiv for key to conventions)

The surviving fabric suggests that all five of the mark II incorporating mills were identical. Only the most complete example - no. 34 which retains both its basement and mill chamber (Fig 52) - will be described here in detail, although a reconstruction of mill 35 mark II is also reproduced at Fig 56. The mill chamber is formed by rubble walls to its rear and side

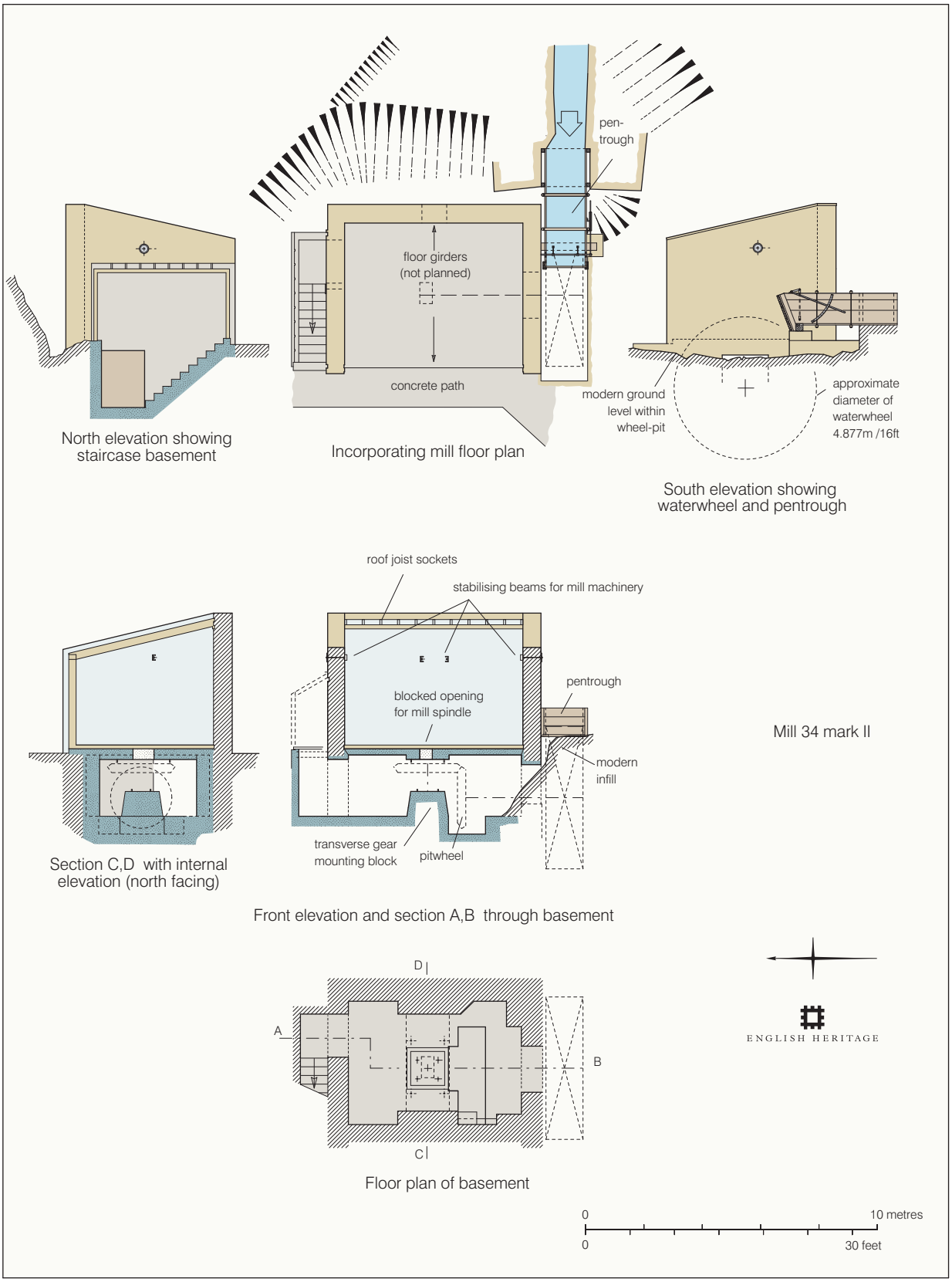


Fig 52. EH plans and sections of incorporating mill 34 mark II(see page xiv for key to conventions)

elevations, 0.63m thick and all quoined at the corners and ends. The rafter line of the former roof is clearly visible in the inner side wall as is the position of the front wall plate. The inner wall-faces below the line of the roof are smoothly cement-rendered to prevent the build-up of gunpowder dust. The stubs of two angle irons are visible embedded high in the rear wall and are tied at the rear by a single iron retaining plate. These angle irons formerly connected with a further large iron or steel beam set in the side walls forming a rigid frame that braced the top of the central mill shaft which rose from the basement and turned the yoke from which the runners were suspended. The floor is of coarse concrete and the tops of six reinforcing I-section iron or steel beams, which formerly carried the weight of the iron pan, are visible running from front to back. The Manufacturing Method Book of 1933/4 (page 5) states that the suspended edge-runner mills were not equipped with drenchers because each was separately housed, and indeed there is no visible evidence for them in any of the four extant mill chambers. The lean-to structure which covered the service access to the basement has been lost but the line of its walls and roofs are clearly visible and the flight of concrete steps survive within a concrete-lined well beside the outer wall (Fig 53). That part of the end wall which was formerly internal is smoothly cement-rendered, as are the walls of the basement itself. Within the basement (Fig 54), the axle of the waterwheel entered at the opposite side from the stairs via a large rectangular opening which no doubt originally contained a bearing box. There is then a deep pit - presumably for a bevelled flywheel turned by the waterwheel axle - and in the centre of the basement is a large, tapering square pier with four upward-projecting pins on its flat top on which the bearing for the vertical mill shaft was formerly mounted. The mill shaft presumably carried a bevelled horizontal wheel which was turned by the axle flywheel. In the ceiling above there is a square aperture, through which the mill shaft passed, flanked to the left and right by the undersides of the six beams visible in the floor surface above. Between the outer two beams, on each side, is a pair of descending pins (four in total) the tops of which presumably secured the iron bed pan (in which the gunpowder charge was incorporated) to the mill floor above.

Fig 53. The staircase to the basement beneath incorporating mill 35 mark II. (NMR DP003443)

Fig 54. The basement beneath incorporating mill 34 mark II, looking south towards the wheel-pit. Note the iron beams in the ceiling which helped support the weight of the edge-runner mill immediately above. (NMR DP003439)

The incorporating mills ceased working when the factory closed in 1935. One mill chamber appears subsequently to have been adapted to accommodate a water turbine powering a small electricity generator (Figs 45 and 55). The filled-in basement level of incorporating mill 36 mark I (one of those decommissioned and demolished in 1928) was exposed, and a light timber-framed housing clad with corrugated-iron sheets erected over it and the adjoining waterwheel-pit: the collapsed remains of the housing lie within the basement, and the line of the pent roof is visible in the north wall of the disused incorporating mill 35 mark II on the opposite side of the pit.

Fig 55.
The header box and Armfield turbine at the exposed part-basement of incorporating mill 36 mark II.
(NMR DP003444)

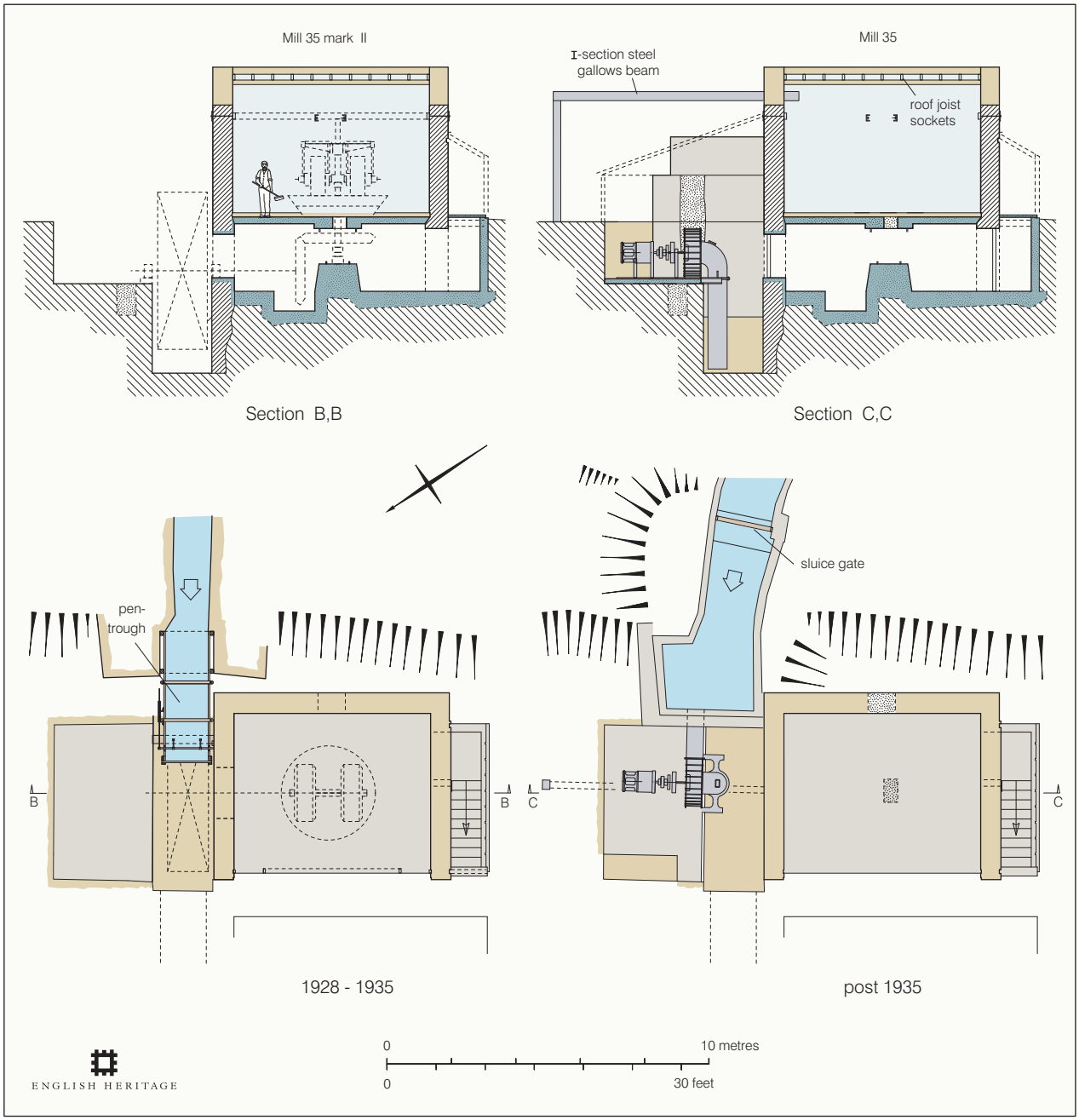


Fig 56. EH plans and sections of incorporating mill 35 mark II, showing its two phases of use
(see page xiv for key to conventions)

The basement was slightly altered, thickly re-floored with concrete and a turbine installed, whilst the waterwheel and pentrough were removed and the end of the leat widened out towards the north and re-walled using concrete blocks - rendered internally - to create a header tank to provide greater water pressure for the turbine (Fig 56). The present turbine has the manufacturer's name J J ARMFIELD, RINGWOOD cast into the side of its casing. It is fed by a square-section supply pipe set into the base of the front wall of the header tank, and has a circular-section discharge pipe feeding waste water back into the wheel-pit to flow away through the original tailrace culvert. It cannot be the first turbine at this location, however, for concrete patching in the front wall of the header tank directly above the supply pipe indicates the latter is a late insertion, possibly put in when the sides of the tank were raised by the addition of a low wall of smaller, poorer-quality, concrete blocks, which carries across the top of the patching (Fig 55). The sides of the leat were evidently relined and raised using identical materials at the same time (Fig 57), suggesting that this phase is contemporary with the heightening of the main headrace in the mid-1960s. The turbine may also have been relocated to its present position from elsewhere within the factory, for it is known that under ICI management an Armfield turbine of 'River' design was purchased for use at Lowwood in 1928 (sections 4.2 and 6.2.1 above), but if it is the same turbine there is presently no evidence for where it was moved from. A large I-section steel gallows beam set into the north wall of incorporating mill 35 above the turbine-house roof and supported at its other end by a steel stanchion, spans the entire turbine house: it was presumably erected to enable the turbine(s) to be lifted in and out of position, although there is now no evidence for pulleys attached to the beam.

Fig 57. The relined leat to incorporating mill 35 mark II. (NMR DP003441)

Expense Magazines / Ripe-Charge House

As already explained (green-charge house, this section above), the provision of expense magazines or similar buildings for the temporary storage of powder as it passed between the various stages of manufacture (including ripe charge emanating from the incorporating mills), was a requirement of the Gunpowder Act 1772. The Act placed limits on the quantities of powder which could be present within process buildings at any one time, and stipulated that magazines or storehouses for the temporary storage of powder had to be built in stone or brick, and be situated at least 50 yards (45.7m) from any mill building (Cocroft 2000, 28). This minimum distance was amended by a subsequent Act of 1860, which defined such buildings as expense magazines, and laid down that they had to be at least 40 yards (36.56m) distant from any process building (Public Statutes General 1860, 616).

Lowwood seems to have operated at least one, more probably two, expense magazines in tandem for much of its working life, on a probable total of four sites. As the first two magazines

were disused around 1861 and replaced by new structures on different sites - known as expense magazines nos. 1 and 2 - the original two will here be referred to as the 'earliest' expense magazines. These earliest magazines were not demolished in 1861, but converted to general storage functions; they appear as buildings 53 and 54 on the 1926 factory plan (Fig 9), which are therefore the numbers used to identify them on all phase diagrams (Figs 132-41) in the present report. Magazines nos. 1 and 2 are also indicated on the same diagrams by the numbers (42 and 48) recorded for them in 1926.

Before the introduction of the internal tramway system to the works in 1869, there is documentary evidence that powder was transported between the expense magazines and the two stoves by boat along the headrace (section 6.2.9 below).

'Earliest' Expense Magazines (buildings 53 and 54)

Under the 1772 Act, therefore, Lowwood would have needed at least one expense magazine when the factory opened for business in 1799. However, the first specific reference to any such building does not occur until almost fifty years later, when the word 'Magazine' appears on the 1846 plan (Fig 4) against two small isolated buildings situated close to the northern end of the headrace. It is unclear whether the published term applies to both buildings or to just one, and if one which of the two is meant, but the term is clearly shorthand for expense magazine rather than store magazine as at this time the latter lay at Roudsea (this section below). The building(s) are still identified as 'Magazine' on the 1863 sale plan (Fig 6), but neither structure could legally have functioned as such after *c* 1861 when a process building (reel and glaze house, this section below) was erected within 40 yards of them. Indeed, in 1926 both were authorised only as stores (Fig 9), with building 53 reportedly used for storing blacklead (section 6.2.2 above).

Despite the fact that both buildings must have been stone constructions, the survey has found no above-ground evidence for either. It is possible, therefore, that they were demolished and their stone used to help shore up the headrace when the latter was heightened in the 1960s.

Expense Magazines nos. 1 and 2 (buildings 42 and 48)

The earliest direct evidence for these two magazines is the 1863 sale plan (Fig 6). However, the schedule in the accompanying indenture describes both as 'new' (section 4.2 above), and the likelihood must be that they were erected *c* 1861 when the construction of a new reel and glaze house at the northern end of the works necessitated the re-siting of the existing ('earliest') expense magazine(s) (this section above).

The 1863 sale plan depicts 'Expense Magazine no. 1' as a rectangular building adjacent to the river, 'Expense Magazine no. 2' as a somewhat squarer building situated next to the headrace due east of the first; later maps and plans (Figs 7-9), however, suggest both buildings were almost square and more or less identical in size. Both occupied isolated positions as required by the Gunpowder Act 1860, at least 40 yards from other danger buildings (respectively, the low press and lower corning houses, and higher stove and 'later' dust house). But despite observing the statutory minimum safe distance, these later maps show that the south-western end of magazine no. 1 which faced towards the low press

house was additionally shielded by a blast wall (called here blast wall BW7); no similar protection is visible around the north-eastern side which faced towards the lower corning house, but the latter building may have been enclosed by its own traverse. Blast wall BW7 existed by 1886 (HF LW/959/323), for the company illegally broke through it when laying a tram line to connect the magazine to the newly-opened cartridge-press house (section 6.2.4 below). Magazine no. 2 seems never to have had its own additional blast protection, although in 1884 HM Explosives Inspectorate ordered blast banks to be erected on either side of the higher stove house (this section below) which would have had much the same effect. The OS first edition map also indicates that by 1888 both magazines had what appear to be covered loading-bays built on to one gable end approached by tram spurs, although these structural additions may have been more akin to enclosed porches designed to permit a second set of entrance doors to be fitted and so make the magazines more secure against intruders (see also Roudsea Magazines, this section below), rather than open-sided loading-bays intended to provide protection from the weather. The 1926 factory plan (Fig 9) portrays both magazines as erected in stone, as required by statute. In 1933/4 the MMB (page 9) refers to 'milled (*ie* incorporated) powder' being brought to the two press houses 'in tubs from the Ripe Charge House by horse drawn bogie' (that is, along the tramway). It is likely that the ripe-charge house in question was actually expense magazine no. 1.

As danger buildings, both magazines would have been cleansed by fire when the factory closed in 1935. Despite having been stone constructions, very little survives of no. 1 and nothing is now visible on the ground to mark the position of no. 2. The site of magazine no. 1 was heavily overgrown at the time of the EH survey, and the only visible structural evidence was the outer face of a low, L-shaped, stone wall; this sits above a platform scarp facing towards the river and probably marks the building's north-east corner. In addition, a low causeway extending up to the platform from the south corresponds to the course of the tram line shown by the second edition OS map. However, there is now no visible ground evidence for the earlier tram line running south-west to the cartridge-press house recorded by the first edition OS map, nor for the short tramway spur which served magazine no. 2.

The north-western end of blast wall BW7 still stands, in places to its maximum original height of *c* 2.5m; the south-eastern end is now mostly ruinous and obscured by tumble, but enough survives to show that both ends of the wall turn out for a short distance through 90^{o} on opposing sides - probably to help buttress it and provide extra strength. Evidence of a butt join close to the north end of the south-western face, however, suggests that this was not the wall's original form. The wall is 1.07m thick.

Press Houses and Press-Pump Houses

After incorporation, the ripe charge was pressed in order to turn it into hard dense slabs ('press cake') which could later be broken down ('corned') into grains of the required size.

By the 1860s Lowwood operated a pair of press houses – unsurprisingly called press house no. 1 or the low press house, and press house no. 2 or the high press house. They should not be confused with cartridge-press houses which were only introduced to the works in the 1880s (section 6.2.4 below). Neither press house is documented before the 1860s, however,

and if a press existed at the works as early as 1799, as claimed by the ICI historian (section 4.2 above), its location is unknown. Both later houses ran on hydraulic power (the putative early press may have been hand-operated): press house no. 1 drew its power from the sawmill, press house no. 2 from the high corning house. Dedicated pump houses existed at both these locations, with hydraulic power conveyed to the presses via pipes.

Both press houses also blew up - no. 1 in 1863, no. 2 in 1903 – and had to be rebuilt (in fact, the initial rationale for the construction of house no. 2 in 1864-5 may have been for it to act as a reserve should there be another accident at the main (no. 1) house); in the case of press house no. 1 it was rebuilt on a new site some 24m south-west of the original position. The 1926 factory plan identifies the two press houses as buildings 41 and 57, which are therefore the numbers used for them in the present report; the buildings destroyed in 1863 and 1903 will be distinguished from their successors by use of the suffixes mark I and mark II in each case. However, both mark II houses had been re-numbered by the company before 1933/4: the low press house as building 42, the high press house as building 70 (MMB, 8). The pump house adjacent to the high corning house for the latter press is shown as building 59 on the 1926 factory plan; the pump house at the sawmill for the low press is not differentiated on that plan, but is here called building 45b.

Press House no. 1 / Low Press House and associated press-pump house (buildings 41 and 45b)

The earliest map evidence for press house no. 1 is the 1863 sale plan (Fig 6), which shows a 'Press House' located close to the river, north-west of the sawmill, close to what had been the 'early' dust house (by this time downgraded to a store); the press house could only have been constructed two years previously, however, for that dust house was still in use until November of that year (dust and dust-charge houses, this section below), and it is known that the company placed an order for a 12-inch hydraulic press from the London firm of Hopkinson & Cope in June 1861 (section 4.2 above); certainly no press house existed at this location in 1846 (compare Fig 4).

The mark I building was damaged in January 1863 and the press-head propelled right across the river in an explosion caused by an initial blow at the glazing house which set off a series of secondary explosions in buildings down wind. Apart from the roof lifting off and the press being upset, structural damage may have been relatively slight or easily repaired for the low press house was reportedly operational again by April, at which time the replacement mark II building was said to contain both 10-inch and 12-inch presses. This evidence fits well with that of the schedule in the 1863 indenture (of which the sale plan forms part) which describes the press house and its machinery as 'new' (section 4.2 above). However, it is probable that the press house which the sale plan depicts is actually the destroyed mark I version, for the building is a different shape to, and lies some 24m north-east of, the mark II building shown on later maps. The newspaper report of the explosion states that the destroyed building was shielded from the low corning house to the north-east by a blast wall and blast bank (*Westmorland Gazette*, 14 Feb 1863), but no such features are portrayed on the sale plan.

Following the explosion, the opportunity appears to have been taken to resite the low press house further away from the low corning house: it now stood actually on the site of, rather than simply close to, the early dust house which seems finally to have been demolished. Later maps (the first two OS 25-inch edition maps and the 1926 factory plan (Figs 7-9)) indicate that the plan of the mark II building - essentially a rectangular structure but with small projections (porches or loading-bays) in the middle of both long walls - changed little during its lifetime. The need for a rear loading-bay is unclear, but was probably included in the original design to facilitate direct passage of press cake between the press house and the nearby no. 1 expense magazine. The entrance may well have been disused after the introduction of the internal tram system to the works in 1869, however, as in 1888 the OS first edition map shows the press house connected to the magazine by a spur coming off a tram line passing in front of the building; the latter also provided a direct connection to the lower corning house. A photograph dating from 1929 (Fig 58) shows the press house was stone built, rendered externally, beneath a slate roof; it also suggests that at this date it had an electricity supply, probably for lighting purposes only.

Fig 58. The low press house mark II viewed, from the south in 1929. (Patterson Collection, ©English Heritage.NMR)

The earliest cartographic evidence for blast protection around the building is the OS second edition map which shows that a blast bank (here called BB1) had been added on the south-west side facing towards the cartridge-press house by 1911; the bank may well have been constructed as early as 1886, however, as part of the conditions which the Explosives Inspectorate imposed on the company for the conversion of the latter building (see cartridge-press house, section 6.2.4 below). By 1926 a similar bank (BB2) had been added shielding the north-east side of the press house (Fig 9), although the occasion of its construction is undocumented. In 1881 the press house was still spoken of as a double press house (meaning it contained two presses) (HF LW/959/097), but by 1933/4 the building accommodated only a single press and this was said to be 'new': it had a ram 18 inches (450mm) in diameter, and was capable of exerting a maximum pressure of 25cwt psi (MMB, 8).

In 1864 it is reported that power for the low-press-house pumps was provided by the sawmill waterwheel (HF LW/1864/075). The wheel was superseded by a Gilkes 40bhp 'Trent' turbine early in 1910 (section 4.2 above), but the practice of using the sawmill to power the low-press-house pumps seems to have persisted until closure in 1935, for the key to the 1926 factory plan names the sawmill as 'Saw Mill & Pump'. According to George Shackley (information from Mike Davies-Shiel and Ron Mein), the press-pump house was actually a small wooden shed (building 45b) attached to the sawmill's south-west gable wall; in 1933/4 it contained 'a set of 4 throw vertical pumps, with 1¼-inch (31.75mm) diameter rams and 3-inch (76mm) stroke at 42 rpm' (MMB, 8).

The present EH investigation found no visible trace of the low press house mark I (it may in part be buried beneath the bed of a later tram line), and very little of the low press house mark II apart from indications of a concrete floor and possibly the stone footings of the north-west gable wall (Fig 142). However, both sites are heavily overgrown. In the case of the mark II building the floor in particular is obscured by leaf mould, ivy and scrub trees; the northern corner is also masked by a pile of what could be demolition débris, but is more likely to be modern dumping. As could be best determined given the level of vegetative build-up, the internal floor area measures *c* 8.75 by 7.01m, with the floor itself made up of a series of concrete slabs 0.38m wide laid 0.09m apart, but this feature is unlikely to date from when the house was first erected. Although concrete began to be used for flooring in the early 19th century, and made its first appearance in government explosives buildings (particularly magazines) a few decades later (Powter 1981, 34), the civil explosives industry was much slower in appreciating the advantages of concrete as a flooring medium (Cocroft 2000, 100-104): a floor of similar design laid in the glazing-house loading-bay area at Lowwood is no earlier than 1928 (glazing house, this section below). Both blast banks BB1 and BB2 protecting the mark II house are well-preserved albeit heavily overgrown, and are seemingly upstanding up to their full original height of *c* 1.2m.

Nothing now survives of the superstructure of the press-pump house at the sawmill, although its site is marked by a platform terraced into the hillside immediately adjacent to the mill's gable wall (Fig 100). It was possibly a brick structure, however, for a few bricks bearing the manufacturer's imprint CLAUGHTON MANOR BRICK C^{o} CATON are scattered across the platform. (Bricks made by the same manufacturer have also been found at the nearby New Sedgwick gunpowder factory (Dunn *et al* 2003, 114)). A sketch of the mill made by Mike Davies-Shiel in 1968 when the gable wall was still standing (Fig 99), indicates the pump house had a pent roof.

Press House no. 2 / High Press House and associated press-pump house (buildings 57 and 59)

Although 'Press Ho[use] no. 2' is depicted on the 1863 sale plan (Fig 6), documentary evidence indicates it was actually not built/operational before 1864-5 (section 4.2 above). It is occasionally referred to as the reserve house, perhaps indicating its intended role when first built, although it was also used to keep up production levels in periods of high demand, and certainly by 1933/4 was in regular, dedicated, use sending press cake to the high corning house (MMB, 10). In 1926 it is described as 'press or cartridge house' (Fig 9), suggesting it was also authorised to press cartridges if needed, but this apparent functional duality seems to be an historical hangover from a short period between *c* 1881 and 1886 when the building was used for pressing cartridges before a dedicated cartridge-press house (building 22) was erected. The issue is discussed in more detail in section 6.2.4 below.

Map evidence shows that the high press house stood at the top end of the works on a narrow spit of land between the river and headrace. It was destroyed in an explosion on 12 March 1903. This mark I press house was not a large building (presumably reflecting its subsidiary role to press house no. 1), measuring only 23 feet long by 20 feet wide (7.01m by 6.1m), and was reportedly lightly-constructed with wooden walls and a corrugated iron roof (Explosives Inspectorate 1903, 4). The walls were only blown outwards a short distance in 1903, and the evidence of the OS second edition 25-inch map (Fig 8) suggests that the

replacement mark II building was initially rebuilt to the same footprint except for the addition of covered loading bays at either end of the south-east wall which fronted a tram line alongside the headrace; the body of the building had been extended towards the north-west by 1926, however (see Fig 9). The OS map also indicates that what seems to be a blast wall (here called BW9) had been erected adjacent to the mark II building's south-west gable wall by 1911, although no blast wall is shown in this location on the 1926 factory plan.

The press destroyed in 1903 was the original machine installed in 1864 (Explosives Inspectorate 1903, 4); few details are known about it, but in 1933/4 the replacement ram in the mark II house was reported as being 14 inches (356mm) in diameter, and was worked up to a maximum pressure of 30cwt psi (MMB, 8).

Right from the outset the high press house was designed to be powered by pumps driven from the high-corning-house waterwheel (HF LW/1864/075 and 080). Although not explicitly stated, these pumps must have been accommodated in building 59 opposite the high corning house which the 1926 factory plan (Fig 9) identifies as 'Pump House'; the hydraulic power would have been transmitted from there to the press house by pipes. All available map and plan evidence portrays the pump house as a simple, small rectangular building which underwent no modification during its lifetime. According to the MMB (page 8), it contained a set of three throw vertical pumps with 1¼-inch (31.75mm) diameter rams and a 3¾-inch (95.25mm) stroke.

As a danger building, the mark II high press house would have been one of those cleansed by fire when the factory closed in 1935. No trace of it or the adjacent blast wall BW9 now survives on the ground, any remaining evidence presumably having been buried and/or destroyed when the headrace was heightened in the 1960s in connection with the modern hydro-electricity station at the southern end of the works. The site of the press-pump house has similarly been flattened or buried, and no surface trace of this building is visible either.

Corning Houses and associated buildings

After pressing, the next step in the manufacturing process was to 'cut' the press cake up into grains of the required size. This process was referred to as corning or granulating. It resulted in angular grains, which subsequently had to be smoothed and polished at the glazing house.

Three corning houses are recorded at Lowwood; all stood on different sites, and each one was also rebuilt at least once. Before 1823 there was only a single corning house at the works, but by 1846 until closure two operated in tandem. In 1846 the first two corning houses were differentiated by the names 'lower' and 'higher'; almost without doubt the higher (more northerly) is the earlier of the two. By 1863, however, the higher corning house had been converted in stages to become a glazing house (this section below), and plans drawn up for a replacement 'high' or no. 2 corning house on a new site. This was initially intended to be a reserve for the lower corning house (which had by this time become the main, or no. 1, corning house at the works), but by 1933/4 it appears to have been in constant and dedicated use cutting press cake produced at the high press house (this section above). By 1859 the corning machines used at Lowwood were of the safer 'Congreve' design which employed rolls to break up the press cake (Cocroft 2000, 63), but earlier machines would have been of the more primitive 'shaking-frame' type comprising oscillating sieves.

As already stated, each corning house was rebuilt at least once, in most (but not all) cases because the previous structure was destroyed in an explosion. However, all three corning houses will be referred to below and on the phase diagrams towards the end of this report (Figs 132-41) by the numbers recorded for them on the 1926 factory plan (Fig 9), namely: building 44 (the lower or no. 1 house), building 50 (the higher house, later the glazing house), and building 58 (the high or no. 2 house); their successive incarnations will be distinguished by the use of mark I, II, III etc. Cartographic evidence suggests most versions of all three houses consisted of two parts or compartments. In the case of the lower and higher houses, this took the form of separate compartments either side of the waterwheel-pit, but in the case of the high house comprised a completely separate structure on the side of the building facing away from the wheel-pit. Both parts of the higher corning house mark II will be referred to simply as building 50, due to the fact that the 1926 factory plan indicates that after 1863 when that house was given over in its entirety to glazing, that number applied equally to both compartments. However, as neither of the subsidiary compartments associated with the lower and high houses is numbered on the 1926 factory plan, they are here called buildings 44a and 74 (again with successive versions distinguished as mark I, II, etc). The function of these subsidiary buildings is uncertain, but some may have been no more than stores for sieves needed in the corning process. The company had re-numbered the high house as building 72 by 1933/4 (MMB, 11).

Higher Corning House (building 50)

The higher corning house - which was located close to the river in the approximate middle of the factory - is almost certainly the original corning house which the ICI historian reported existed when the works opened in 1799 (section 4.2 above). However, the earliest indisputable evidence for its existence is not until July 1823, when it is recorded that the building blew up, killing two men and burning another, and damaging the Low Wood Inn on the opposite side of the river. As the contemporary press report (*Westmorland Gazette*, 19 Jul 1823) refers to the destroyed building using the definite article, the implication is that at the time there was only a single corning house at the works. This is in contrast to 1846, when two houses (differentiated as 'Higher' and 'Lower') are recorded. Information in the 'Explanatory Remarks' on the 1846 plan (Fig 4), however, strongly suggests that the scene of the 1823 explosion was the higher corning house. This is also the logical inference to be drawn from the relative positions of the two houses: the higher corning house stood at the end of its own dedicated leat, whereas the lower corning house was supplied by a subsidiary leat coming off that to the higher house, and must therefore have been secondary to it.

No details are known about the structure or machinery of the mark I higher corning house (that is, the pre-1823 building), although the 1846 plan shows the replacement mark II house consisted of two unequal-sized compartments either side of a central waterwheel-pit. It is probably reasonable to suppose that its predecessor followed a similar layout. Before 1863 one of the two compartments in the mark II house (probably the southernmost) had been given over to glazing, for the machinery exploded in January of that year destroying both parts of the building, and setting off secondary explosions at the lower corning house and low press house (section 4.2 above).

Shortly after the accident, the company took the decision to reconstruct the entire building as a glazing house (HF LW/1863/035). However, a sketch plan made in May 1863 (HF LW/Misc/074, reproduced here as Fig 59) in connection with the reconstruction records the internal dimensions of the foundations of the destroyed building. Both compartments measured 22 feet (6.7m) wide, with the northern compartment just over twice as long as its southern counterpart at 39 feet (11.89m) compared to 19 feet (5.79m). A transverse 'Foundation Wall built on Rock' divided

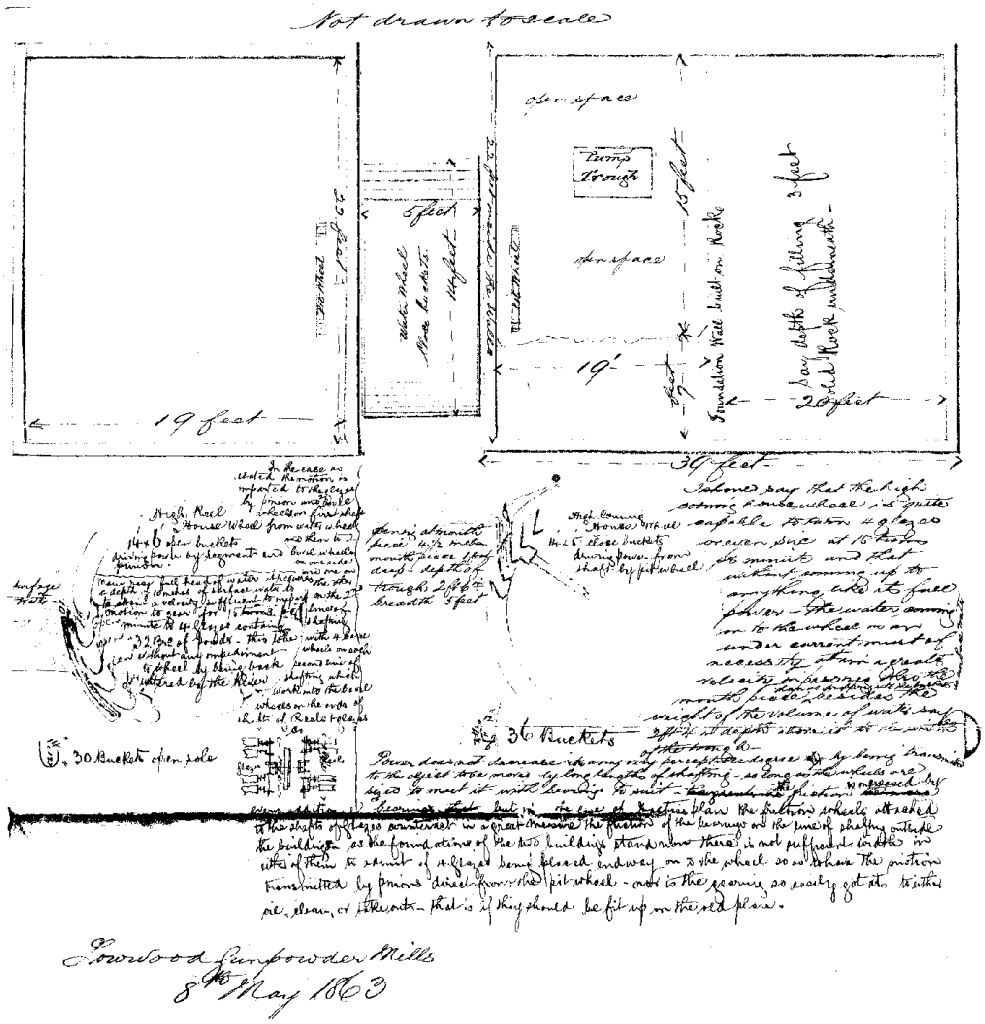


Fig 59. The 1863 sketch plan showing the ruins of the higher corning house prior to rebuilding as the glazing house. (Heritage First!, copyright reserved)

the north-eastern compartment into two almost equal parts, with the more southern part measuring 15 feet wide by 19 feet long (4.57m by 5.79m) and annotated as 'open space' but shown containing a 'Pump Trough' and 'Pit Wheel', and the other part described by the comment 'Say depth of filling 3 feet Solid Rock underneath' implying the existence of a suspended or raised floor. The south-western compartment likewise contained a 'Pit Wheel'. The waterwheel-pit between the two compartments was also 22 feet long, and although its width is not noted it housed a wheel 14 feet in diameter by 5 feet wide (4.27m by 1.52m) shown as almost touching the side walls; the wheel had 36 'Close buckets'. The implication of this sketch is that beneath each compartment was a basement measuring 15 feet by 19 feet, whose function was to accommodate and give access to a pitwheel and associated shafting driven from the waterwheel axle, and which in turn transferred power to machinery on the floor above. If the presence of basements either side of the wheel-pit was part of the original design of the mark II corning house as reconstructed following the 1823 explosion, then it indicates that both compartments were designed to accommodate powered-machinery

right from the start; the (less likely) alternative is that one of the basements dates only from the conversion of the compartment above it to glazing sometime after 1846. The presence of a pump trough is unexplained.

Very little of the superstructure of the mark II corning house is likely to have survived the rebuilding in 1863. However, elements of the wheel-pit and internal basement levels are discernible within the standing ruins of the replacement glazing house, and are described in connection with the account of that building (this section below).

Lower Corning House / Granulating House No. 1 and associated building (buildings 44 and 44a)

The mark I version of the lower corning house – which stood adjacent to the river *c* 75m south-west of the higher corning house - was erected sometime between 1823 and 1846 as shown by the explosion of the higher corning house in 1823 (this section above) and the depiction of the house on the 1846 plan (Fig 4). Within this broad timeframe, the most likely date for its construction is shortly after 1828 when the company's renewal of the factory lease (over twenty years before it was due) suggests a general desire to invest in new facilities (section 4.2 above). The corning house remained in use until the factory closed in 1935, although it was re-constructed on three occasions: following explosions in 1863 and 1868, and modernisation around 1928.

The 1846 plan portrays the original (mark I) house as made up of two, unequal-sized, compartments either side of a central waterwheel-pit (the smaller compartment will here be differentiated from the larger – presumably the corning house proper - by use of the number 44a). The plan also shows that the wheel was supplied by a leat taken off that to the higher corning house, with the level of water in the leat regulated by an overflow channel some 35m north-east of the building: this channel discharged directly into the river. It was probably for this corning house that the new corning machine of Congreve type purchased from the London company of Hopkinson & Cope in 1859 at a cost of £341 10s 0d was intended; the machinery was installed by the firm of Stevenson of Preston (HF LW/958/137). However, the mark I house blew up in January 1863 (section 4.2 above), and no further details about it are known.

Little is recorded about the mark II lower corning house (which replaced the mark I house) either, apart from its outline plan plus minor details on the machinery which was again of Congreve type, this time commissioned from the firm of Hastie & Co (*eg* HF LW/958/552, 594, 738, 745-6, and 752-3). The 1863 sale plan (Fig 6) suggests that only the corning house proper, and not building 44a, was reconstructed at this time. It was only five years, however, before the mark II corning house was itself destroyed in an explosion on 28 November 1868 which also killed the five men working inside. The local press report of the resulting coroner's inquest (*Westmorland Gazette*, 5 Dec 1868) contains few clues as to the layout or structure of the building, but the fact that the walls were said to have been completely flattened while the waterwheel was left undamaged suggests that the latter lay low down within its pit, possibly with power transmitted from it to the corning machinery via a pitwheel and shafting housed in a basement level.

On 3 May 1869 the company directors gave authorisation for the construction of a replacement (mark III) house on the same site as its destroyed predecessor (HF LW/1869/025). Although the machinery seems to have been supplied once more by Hastie & Co, it was very much to the company's specification since their primary concern was to reduce the number of men required to operate it from the five or six of the mark II house down to two, in order to minimise the number of potential fatalities in any future explosion (section 4.2 above). The first two editions of the OS 25-inch map (Figs 7 and 8), surveyed in 1888 and 1911, indicate that the mark III house had a somewhat different plan from the building it replaced, and superficially at least had more in common with the earlier mark I house in that it once more consisted of two parts either side of the waterwheel-pit, but with each now turned through 90° so that the long axis was oriented along the leat rather than at right angles to it. The machinery must have been housed in the structure on the north side of the wheel-pit for it is this building which is labelled as 'Corning House' in the key to the 1926 factory plan (Fig 9); the function of the other compartment (here called building 44a mark III) is unknown as it is not identified on that plan. One possibility is that it was a belt-drive house similar to that which was tacked on to the outside of the blast wall enclosing the machinery in the later mark IV design of the house (see below), but this is perhaps unlikely since the belts would then have had to pass over the top of the wheel-pit making maintenance difficult. Structural details are sparse, but the roof of the new corning house reportedly had lead ridging (HF LW/1869/046).

The OS maps of 1888 and 1911, and the 1926 factory plan, all agree in showing a tramway spur branching off the main line between the low press house and glazing house, and terminating at a door near the west end of the mark III corning house: this was presumably the route by which powder arrived at the building from the press house. All three maps also agree in showing another spur originating at a small structure (unnumbered by the factory plan, but called building 76 for present purposes) to the rear of the corning house, which rejoined the main line near the glazing house: this was presumably the route along which corned powder travelled prior to glazing. By 1911 a second short spur had been added starting from immediately west of building 76 and leading back towards expense magazine no. 1, presumably to enable corned powder to be stored temporarily at the magazine if the glazing house was not ready to accept it. This suggests that building 76 may have been little more than a covered loading area, but as its true purpose is unknown it is discussed more fully in section 6.2.7 below.

Fig 60. Lower corning house mark IV, viewed from the north in November 1928. (Patterson Collection, © English Heritage.NMR)

The mark III corning house and its attendant building(s) were still extant in 1926 (Fig 9). However, by November 1928 all had been swept away and replaced by a totally new, mark IV, house as shown by a contemporary photograph (Fig 60) and accompanying caption which describes the

building as the '(New) Corning House'. This mark IV building was evidently erected by ICI as part of their modernisation programme, although no specific mention of its construction has been found in surviving documents (section 4.2 above). The MMB (pages 11-14) contains a description of the corning machinery it contained, said to be of 'Nobel' type: this machine was fitted with six pairs of rolls, a shaker box carrying all the sieves, and an inclined reel sieve, all powered by a waterwheel. Of the rolls, three pairs were cracker rolls with pyramidal teeth of successively shallower depth, and three pairs were smooth rolls, each with one roll fixed and one sliding.

Although the mark IV corning house was either dismantled or deliberately burned down in 1935 when the works closed, the concrete floor and stone back and side walls of the chamber which housed the corning machines still survive in good condition, together with the concrete floor of the belt-drive house which was attached to the outside of the chamber's back wall (Fig 62). The stone-lined waterwheel-pit and associated water-power features which lay rearwards of the belt-drive house – many no doubt retained or adapted from those which served the mark III house - also survive, although these are generally less well preserved. The extant structures were all cleared of tree and ivy growth prior to investigation by EH.

The three standing walls of the main corning chamber (Fig 61) are built of slate rubble with rock-faced quoins at the corners and concrete coping along the top; they are 0.92m thick and belong to a building which was 16m wide and 7.6m deep. The rear wall is 6.9m high, but the side walls slope gently down to the front where they stand 5.5m high implying that the building had a single-pitch roof; this is confirmed by the 1928 photograph (Fig 60) and by the evidence of the inner faces of the three walls which have scars where the roof structure abutted them. Slate water tabling 0.7m below the tops of the three walls protected the upper edge of the roof from seeping rain. The interior of the corning house has a concrete floor. The side and rear walls below roof level are plastered and were originally also boarded out for exposed strips of rubble on the internal walls indicate that vertical timber battens were first nailed to the wall at approximately 0.55m intervals and that the masonry between them was then plastered (the plaster has partially leached under the battens); planks or boards were then presumably attached to the battens to create an environment in which as little powder as possible could settle. The plaster and battens can be seen to have stopped at the underside of the lost single-pitch roof, the position of which is indicated by areas of exposed stone rubble. The roof was supported by twelve rafters, the holes for the upper ends of which survive in the back wall; the holes are directly above a lip of plaster which creates a cornice-like band sealing their underside.

Fig 61.
The interior of the lower corning house mark IV, viewed from the north-east.
(NMR DP003475)

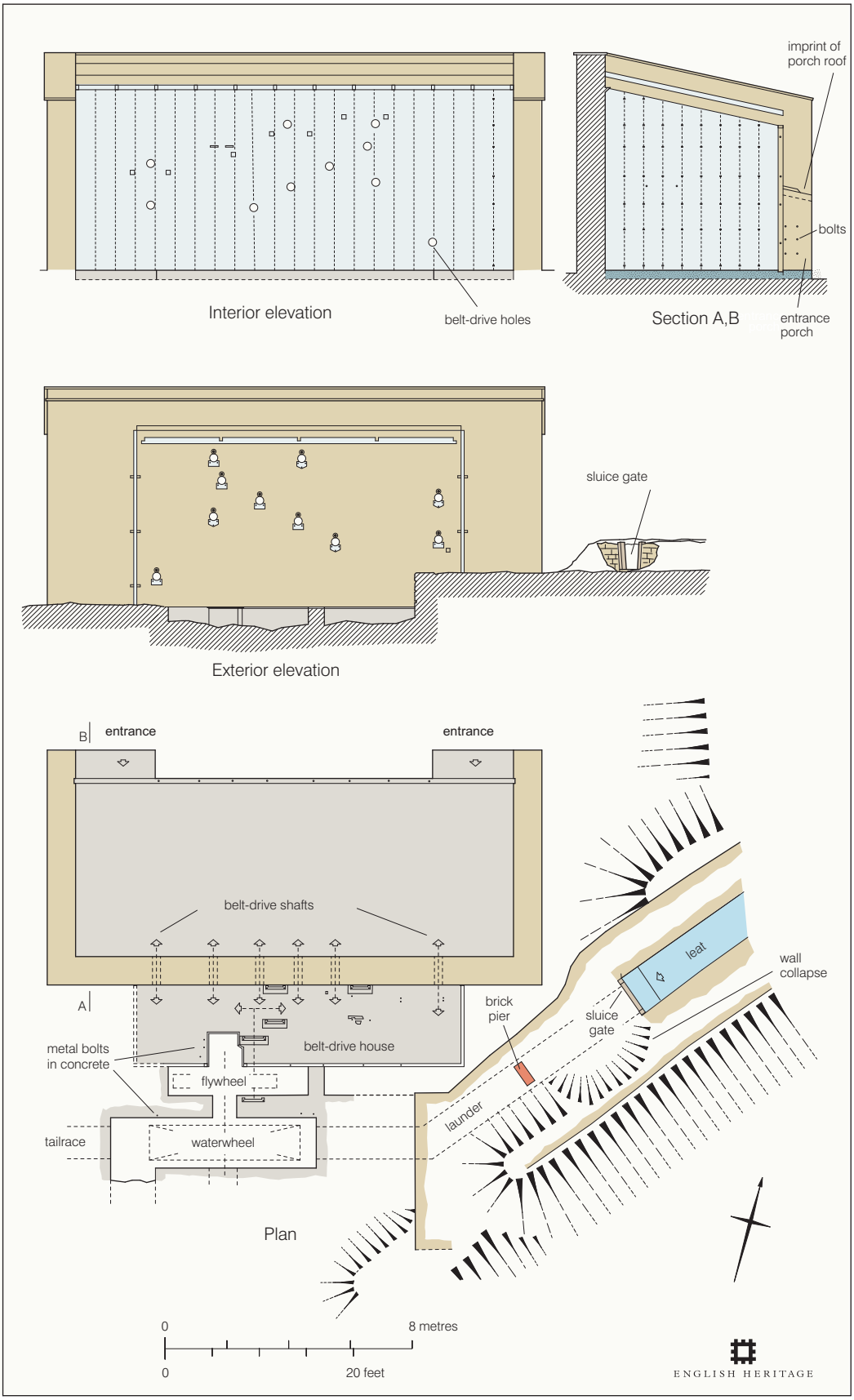


Fig 62. EH plan and elevations of the lower corning house mark IV (see page xiv for key to conventions).

The 1928 photograph (Fig 60) shows that the front of the building was formed by a light-weight timber-framed screen, which structural evidence indicates was set back 0.92m from the front ends of the side walls. The screen is shown with a framework of square panels, eleven wide and four tall, which contained two doorways and a series of windows symmetrically disposed across it. The doorways were at each end, and although the concrete standings in front of them can still be identified nothing survives of the timber porches shown in the photograph. These porches, or loading-bays, were open-sided structures with single-pitch roofs supported at the front by three timber posts, and presumably projected out over a tram line which ran across the front of the building. The quoins next to both doorways have four rows of holes (a few containing brass screws) which must have secured some form of protective sheeting over their rough surface. The windows in the screen, which all had fixed frames of small-pane glazing, were set in two heights in alternate bays, the lower four windows being two panels high, the upper five windows each filling just a single top panel. The blind panels appear to have been filled with plywood or similar sheeting. The screen can be seen, from the surviving masonry, to have been bolted to the side walls of the corning house and to its concrete floor. Vertical strips of exposed rubble in the side walls, bounded to the rear by the plastered wall and to the front by cement sealing, show where the timber uprights were located. Both were secured by four iron bolts which project from the masonry and have washers and screw-threaded hexagonal nuts at their outer ends. A 10mm deep, 150mm wide channel in the concrete floor of the corning house, between the two end doorways, has eight iron fixing bolts for the base plate.

Nothing is known about precisely how the corning machinery was arranged inside the building or how it was driven, but details of the latest corning house at the Blackbeck Gunpowder Works, plus photographs of it taken after it burned down in June 1929 (Tyler 2002, 239; Dunn *et al* 2005, 65-70, figs 29 – 31), offer useful clues. In 1968 Mike Davies-Shiel published a reconstruction drawing purportedly of the Lowwood corning machine, but the machine shown is actually a generic reconstruction based on his own recording of the pattern of line-shaft openings in the rear wall of the Lowwood corning house, combined with unspecified evidence from the Blackbeck and Elterwater gunpowder works and comparison with the corning machine which was then still in operation at the Ardeer works (Marshall and Davies-Shiel 1969, 82-3); it therefore does not accord fully with the written description of the Nobel machine installed at Lowwood given by the MMB (this section above).

The Nobel corning machine is likely to have occupied the inner part of the corning house, the area nearer the front being kept clear to service it. Individual parts of the machine would have been belt-driven from pulley wheels mounted on line shafts. The walls of the corning house are built of slate rubble, but where the line shafts pass through, the latter are set in square, concrete housings with 260mm diameter circular openings and associated cast-iron fittings (Fig 63). The openings are of two types: six have shuttered concrete sides (they are the four openings in a diagonal line and the two outer lower openings) and four have ceramic-pipe linings. Shafts – more particularly belt-drives - must have passed through these openings, and brackets to support them were evidently attached to the inner face of the wall. The brackets do not survive, but their

outlines are visible as rectangular impressions with angled tops in the plaster around the openings. These plates were held in place by bolts attached to mounts on the outer face of the wall: circular cast-iron tie discs with a single central bolt were set above the opening, and rectangular plates (some with angled bases) below them. The shape of the bottom plate does not equate with the differing ways the openings through the wall were formed. The pattern of circular openings exactly matches those in the reinforced concrete walls of the corning houses built at the Oare Gunpowder Works at Faversham in Kent in 1926 and at the Marsh Gunpowder Works, again at Faversham, which is almost certainly contemporary in date (Cocroft 1994, 14 and fig 14; www.faversham.org/photogallery/oare_gallery.asp; NMR No. TR 06 SW 64 and photographs).

Fig 63. The outside of the rear wall of the lower corning house mark IV, showing the scar of the now vanished belt-drive house and the circular openings for the line shafts. (NMR DP003473)

The corning house was always water powered, with drive transferred from a waterwheel to the corning machinery via line shafts housed in a belt-drive house attached to the outer face of the corning house's rear wall. The belt-drive house does not survive, but it stood on a concrete base and was rectangular in plan with timber-framed walls and almost certainly a single-pitch roof: its rectangular plan, which measured some 10.5m by 2.5m, is known from channels in the concrete which still retain the iron bolts for securing the base plate of its timber frame. Vertical plaster strips on the rear wall of the corning house respect the posts at the inner ends of both side walls, timber plugs serving to secure them in place. The top of the structure was level: three corbelled-out courses of slate contain recesses for the upper ends of five rafters, while above them the wall has a projecting course of slate water-tabling to keep the rain out. The concrete floor has a number of iron bolts and shallow recesses in its surface (Fig 64) which indicate where the supports for the line shafts were located.

Fig 64. Imprint of one of the line-shaft supports in the floor of the belt-drive house attached to the lower corning house mark IV. (NMR DP006444)

The pit of the former waterwheel survives (Fig 62), although partially infilled and constricted (weirs and leats, section 6.2.1 above, and Fig 23), together with a linked, smaller pit to its north which may have contained a flywheel. The leat which had served all three earlier corning houses on the site was retained, with water probably led to the waterwheel through a wooden launder supported by a brick pier.

High Corning House / Granulating House No. 2 and associated building (buildings 58 and 74)

The high corning house stood adjacent to the top end of the headrace, just below the Eel Dams weir. Although depicted on the 1863 sale plan (Fig 6) as 'Granulating House no. 2',

documentary evidence suggests it was not built and operational for another couple of years: the building's stone foundations still had to be laid in February 1864, and powder was not corned here until October 1865. The machinery was again supplied and fitted by the firm of Hastie & Co of Greenock, at a cost of £922 5s 0d (section 4.2 above, and HF LW/1864/037 and LW/958/075 and 111). However, this mark I building and the machinery it contained had an operating life of only 5½ years, for shortly after midday on 8 March 1871 an explosion destroyed or displaced much of both. According to a local press report (*Westmorland Gazette*, 11 Mar 1871), the superstructure comprised timber walls and a slate roof; only the stone foundations remained intact.

It took at least a year for the house to be rebuilt and brought back on-line (HF LW/1872/005). Although no details have survived on the designs or materials of the new, mark II, house, Hastie's repaired the machinery at a cost of £510 (HF LW/1871/030). According to the OS first edition 25-inch map (Fig 7), surveyed in 1888, the replacement structure was broadly square in plan and powered by a waterwheel situated in a pit external to the north-east wall; small porches or covered loading-bays are also depicted protruding from the south-west and south-east walls where a branch and subsidiary spur off the works tramway system terminated, but two apparent projections on the north-west side of the building facing towards the river are of unknown purpose. Slightly different footprints shown on later maps and plans (Figs 8 and 9) suggest alterations had been made to the building before 1911, and again before 1926. The 1926 factory plan also portrays a small breakwater protecting the waterwheel-pit. This was presumably a late attempt to protect the wheel from damage when the river was in spate: a similar device is recorded protecting the waterwheel at the reel and glaze house (this section below).

All the maps and plans agree in showing a small building situated on the opposite side of the waterwheel-pit to the mark II corning house. This was a pump house (building 59, this section above) for the nearby high press house which drew its power from the high corning-house waterwheel. The function of a second structure (building 74, section 6.2.7 below) depicted a little to the south-west of the corning house is unknown, but its size, shape and general relationship to the high corning house is reminiscent of that of building 44a to the lower corning house, suggesting it may have served a similar function.

The evidence of the MMB (pages 11-15) shows that the original Hastie corning machine was still working in 1933/4. It consisted of six pairs of rolls, three pairs with pyramidal teeth and three without any teeth. The three pairs of toothed rolls were arranged in a vertical column, with broken-up lumps of press cake fed in at the top and allowed to pass between each pair in turn. At the bottom of the column the roughly corned powder discharged via a hopper chute into a bucket elevator which raised it to the top of the column of smooth rolls. Once through these, the powder fell on to a sloping sieve-frame which oscillated with a circular motion driven by a 4-inch (101.6mm) crank at 104 rpm. This frame contained nests of meshes of different gauges which sorted the grains into barrels according to size; over-sized grains were returned to the top of the smooth rolls to pass through the machinery a second time.

As a danger building, the high corning house would have been one of those cleansed by fire when the factory closed in 1935. Any surviving remains were presumably further bulldozed and/or had concrete rubble dumped over them in the 1960s to help shore up the sides of the heightened headrace to the hydro-electricity station. All that is now visible on the ground (Fig 142) is a stretch of stone walling revetting the river bank and defining the edge of the platform on which the corning house stood, a possible short length of its southern gable wall, and a slight linear depression which corresponds to the position of the infilled wheel-pit; no evidence of the documented breakwater was observed in the river.

Glazing and Reel Houses

Corning broke the press cake down into angular grains. These were subsequently smoothed and polished by a process known as glazing – tumbling the grains in special wooden barrels for several hours, for part of the time with graphite added. Powders requiring an extra polish were also reeled - that is, tumbled in linen barrels - sometimes with more graphite added.

There is no direct evidence that Lowwood glazed or reeled any of its powder before the 1860s. In January 1863 one half of the higher corning house - which had reportedly been converted into a glazing house – blew up, but it is unclear how recent the conversion was: certainly the 1846 plan does not describe any part of the building as in use for glazing (compare Fig 4). After the explosion, it was given over in its entirety to glazing, although the 1926 factory plan's description of it as 'Reel & Glaze House' indicates that at some point (perhaps only briefly in the 51 years since the passage of the 1875 Explosives Act) it had also contained reels. However, as all other available evidence suggests that the building operated solely as a glazing house (particularly following major reconstruction *c* 1928), that is how it will be referred to here. A separate reel and glaze house was constructed sometime between 1861 and 1863; after *c* 1875 it also operated as a dust house, but ceased to be used for glazing *c* 1931 following which it was known as the reeling, dusting and sizing house (see dust and dust-charge houses, this section below).

Both glazing/reeling houses consisted of separate compartments either side of a central waterwheel-pit. In 1903 the wheel at the glazing house was reportedly replaced by a water turbine, but the reel and glaze (later the reeling, dusting and sizing) house retained its waterwheel right up to 1935. The 1926 factory plan (Fig 9) identifies the respective houses as buildings 50 and 55/56, which are therefore the numbers used for them below and on the relevant phase diagrams (Figs 135-41) in the present report. However, both had been re-numbered by 1933/4: the glazing house as compartments 47/48, the sizing, dusting and reeling house (formerly the reel and glaze house) as compartments 68/69 (MMB, 19 and 24).

Before the introduction of the internal tramway system to the works in 1869, there is evidence that powder was transported between the reel and glaze house, the two stoves, and the expense magazines bordering the headrace, by boat (section 6.2.9 below).

Glazing House (building 50)

Building 50 seems to have originated in 1799, but all available evidence suggests that it was used exclusively for corning until at least 1846, at which time it was known as the higher

corning house (this section above) and consisted of two, unequal-sized compartments either side of a central waterwheel-pit. In January 1863, however, when the building was severely damaged in a serious explosion which also affected neighbouring houses and killed six men, one of the two compartments contained glazing machinery (section 4.2 above). A local press report (*Westmorland Gazette*, 14 Feb 1863) states that there were six glazing barrels in the building at the time, all of which ran overnight (presumably because the waterwheel generated insufficient power to operate both corning and glazing machinery simultaneously). The evidence for the plan of this joint corning/glazing house has already been reviewed (higher corning house, this section above), and the observation made that both compartments seem to have been constructed over basements housing pitwheels and shafting which transferred power from the waterwheel axle to the corning and glazing machinery on the floor above.

Immediately following the accident, the company took the decision to reconstruct the destroyed building as a dedicated glazing house, and commissioned replacement machinery from the firm of Hastie & Co. The initial intention seems to have been to keep the capacity of the new house at six glazing barrels - now to be arranged three either side of the waterwheel - but with room for an extra barrel to be added in each compartment should the wheel prove powerful enough to drive eight in total. In addition, the company was desirous that the gearing for the machinery should be external to the building for ease of maintenance (HF LW/1863/035). However, an annotated sketch of the destroyed building, dated 8 May 1863 (Fig 59), suggests that the existing foundations were found to be too narrow to allow four barrels to be placed in a single row end on to the wheel, and the MMB (page 19) records that there were only six barrels in the house as late as 1933/4.

Field and later map evidence indicates that the new glazing house reused the foundations of the higher corning house, but with the north-eastern compartment shortened and the south-western compartment lengthened to make both the same size; field evidence also indicates that the gearing basements were retained in the rebuild. The company considered using galvanised iron to roof the glazing house, but seem to have been deterred from use of this material by their local building contractor, Charles Blades (HF LW/1863/030, 031 and 046). In 1869 a tram line was laid outside the front wall of the glazing house, facing away from the river. Porches or covered loading-bays shown on the OS first edition 25-inch map of 1888 (Fig 7) suggest that at that date each compartment was entered through a single doorway located at the outer end of that wall, although in 1911 the OS second edition map (Fig 8) shows a porch outside the north-eastern compartment only. A photograph of the glazing house taken in 1928 (Fig 65)

Fig 65.
The front of the glazing house, photographed from the south in August 1928 prior to reconstruction by ICI. (Patterson Collection, ©English Heritage.NMR)

seems to show both porches (although that outside the north-eastern compartment is almost completely lost in shadow) and indicates that, by then, each compartment also had a second doorway in the front wall close to the waterwheel-pit.

The building was altered as part of ICI's general modernisation of Lowwood in 1928-9, for a slightly later photograph captioned 'Reconstructed Glazing House' shows the building with a new open-fronted covered canopy supported on fourteen timber posts (the central eight posts set slightly forward of the three at either end) running the full length of the building, protecting and sheltering the tram line (Imperial Chemical Industries 1929, 341 bottom; a copy of the photograph also forms part of the Patterson Collection at the NMRC and is here reproduced as Fig 66). Both doorways in each compartment were retained - all with part-glazed doors with rectangular overlights - and a fixed-frame window with small-pane glazing inserted between each pair; the windows have timber lintels. The masonry is exposed around both the central windows, but closer to the doorways it has been rendered. The rendering equates with the areas in front of all four doorways which have low timber buffer beams extending out to the inner edge of the tram line, their purpose being to prevent material encroaching on the tramway.

Fig 66. The glazing house as reconstructed in 1929, viewed from the south. (Patterson Collection, ©English Heritage.NMR)

Maps indicate that a wall existed beyond the tram line between at least 1911 and 1926 (Figs 8 and 9). This may have been a blast wall (here called BW8), but it is not visible on the 1929 photograph suggesting that it was demolished as part of the modernisation.

Tyler (2002, 152) suggests that new glazing drums were also installed *c* 1928 as part of ICI's modernisation programme. These were capable of extracting more of the residual moisture and so removed the need to stove loose powder. In 1933/4 the new glazing drums were turned by a 25bhp (18.75kW) water turbine capable of driving all six at 10rpm (each loaded with eleven or twelve barrels of light-density powders), or five at the faster rate of 12 to 13rpm deemed necessary for ordinary blasting powders (MMB, 19-23). It is unclear whether this particular turbine was installed at the same time as the new drums, but it is likely that the house had been turbine-powered since 1903 for in February of that year the company had received a quote for a 12.7kW turbine in connection with the glazing house from the Kendal firm of Wright, Heaps and Westwood (section 4.2 above). In 1933/4, most powders were glazed for between 6½ and 7½ hours, with the graphite added after about 5 hours.

The glazing house was set alight when the works closed in 1935 - as shown by charring on surviving structural timberwork. It has since fallen into ruin (Fig 67) with collapsed masonry

now obscuring much of the interior (including the internal faces of the walls) and part of the external face of the front wall. However, sufficient fabric survives (Figs 68 and 69) to show that the building constructed in 1863 – the final appearance of which is known from the 1928 photograph (Fig 65) - was single-storeyed over a part basement, was built of coursed stone rubble with a slate roof and incorporated masonry of earlier date, all of which was subjected to considerable further modification in 1929. Standing trees were felled from within and around the extant ruins prior to investigation by EH, but no attempt was made to remove ivy growth from the walls. Sheets of corrugated iron lie scattered over the course of the tramline in front of the building north of the wheel-pit, but it is unclear where these originated. They are unlikely to have formed part of the glazing house roof as this is known to have been slated both before and after the building was reconstructed in 1928/9; they may, therefore, represent modern dumping.

Fig 67.
The ruins of the glazing house, viewed from the south following felling of standing trees.
(NMR DP006445)

The glazing house stands on the site of what was, before the explosion of January 1863, the higher corning house. That earlier building had been terraced into the slope of the river bank to create basements for the drive mechanisms of machinery housed at ground-floor level, and some of the surviving masonry at basement level belongs to the corning house. But above basement level, the coursed stone rubble walls were built anew in 1863 and belong to a single-storey building which was gabled to north-east and south-west and comprised a pair of equal-sized compartments separated by a waterwheel-pit. Both compartments are 6.78m wide by about 9.02m long; their width is sufficiently close to the 22 feet (6.71m) recorded for the destroyed higher corning house (this section above) to indicate that the positions of the front and rear walls of that building were retained, but neither of the new lengths is close to the 19 feet (5.79m) and 39 feet (11.89m) recorded for the compartments of the earlier building. The front walls of the two compartments of the 1863 building certainly had doorways close to their outer ends, as covered loading-bays shown on the 1888 OS map indicate, but whether they also had doors close to the central wheel-pit is less certain. These latter doorways were there by 1928, as the photograph (Fig 65) shows, but whether they date from 1863, as seems likely, cannot be proven. By June 1929 (Fig 66), as part of the major remodelling of the works, this inner pair of doorways was widened to take double doors, and windows with splayed inner reveals were inserted in the wall between the two doorways in each compartment. At the same time, the two canopies over the outer doorways were replaced by a canopy which extended along the full length of the front elevation and projected out over the tramway. Concrete-slab floors were also laid in the loading bays in front of the four doorways, similar to the floors which survive in the low press house and the 'final' packing house (this section above and below). The canopy does not survive, but all the doorways and windows do, although none to their full height. The gable walls are blind, but the rear walls overlooking the river each have three ground-floor windows, all likely to be

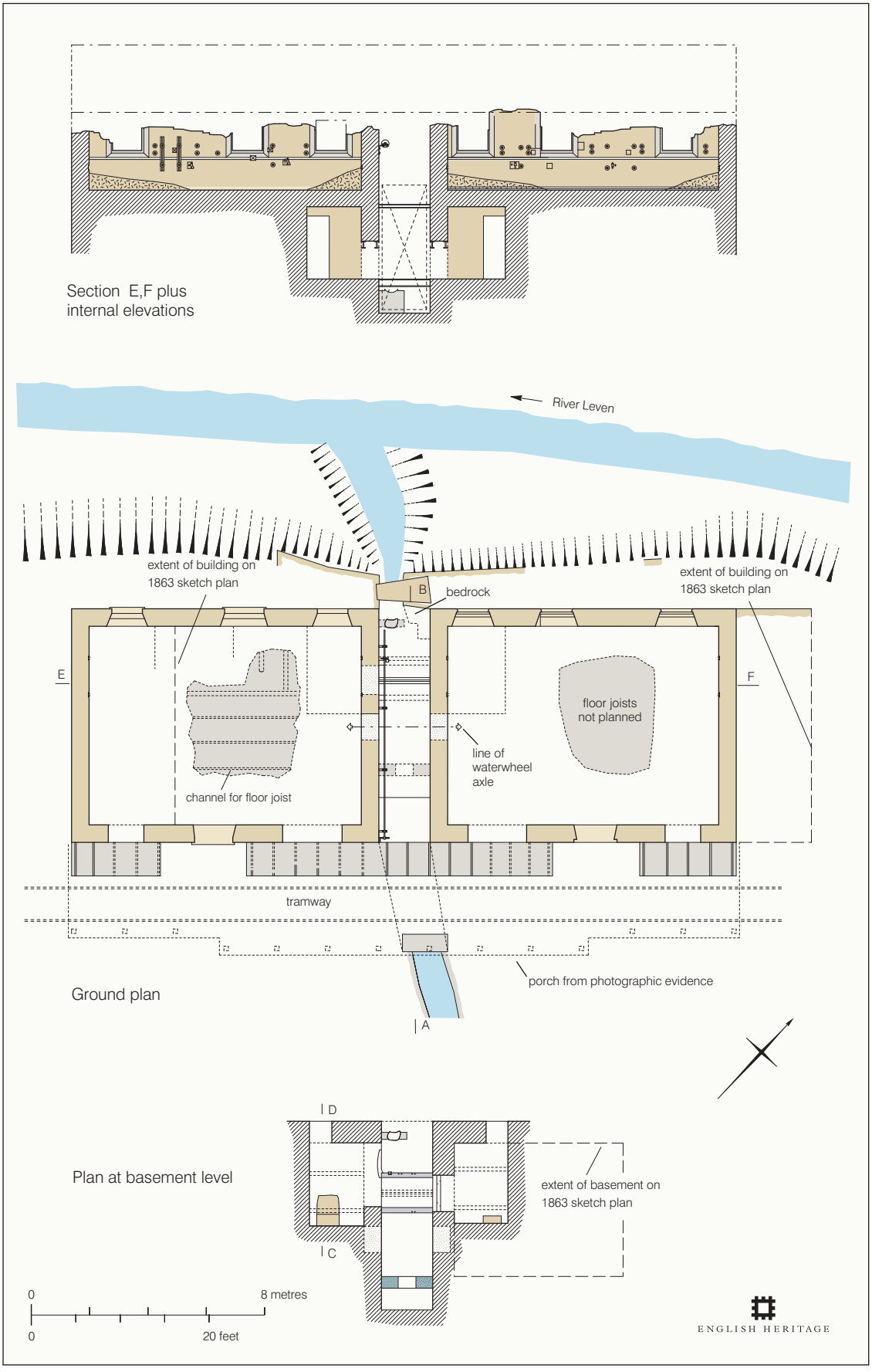


Fig 68. EH plans and long section of the glazing house (see page xiv for key to conventions).

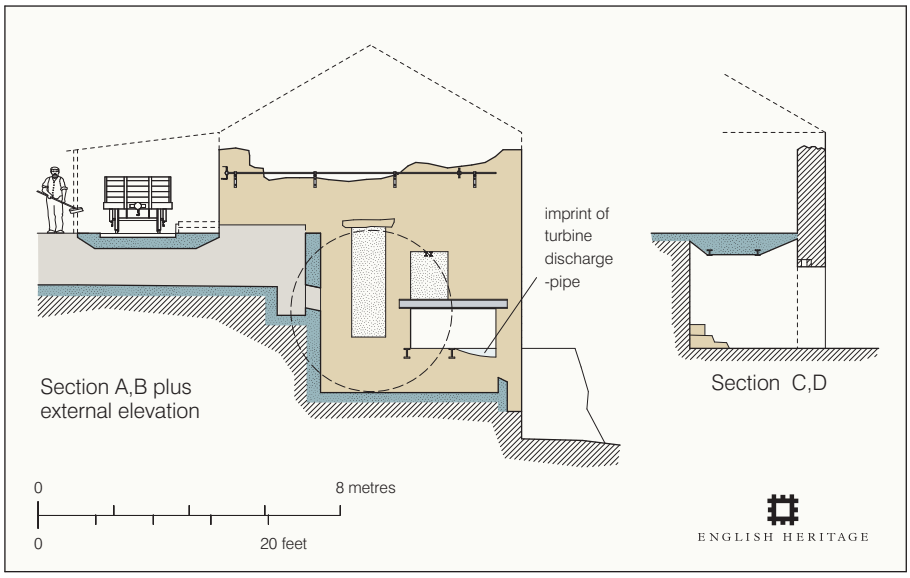


Fig 69.
EH cross sections of the glazing house (see page xiv for key to conventions).

part of the original 1863 build. They have splayed reveals and lack their heads, which would have been formed by the timber wall-plate. One of the windows in each compartment is directly opposite the doorway at its outer end, while the other two lie in the inner half of each compartment, one close to the wall beside the wheel-pit. The pairs of windows are likely to have lit working areas where machinery was driven from shafts rising from the basement, while the outer ends may have been assembling or service areas where material was received and despatched. The inner faces of the walls of both compartments have several horizontal rows of 40mm deep timbers set in them: they may have strengthened the masonry in the manner of ties, or have supported plank panelling. The function of various iron bolts, plates and tie-straps in the rear wall is uncertain: they most probably were intended to strengthen it, and date from *c*1928 when new glazing drums were installed.

Part basements under the inner part of each ground-floor compartment of the 1863 glazing house, next to its central waterwheel, housed flywheels and shafts which transferred power up to glazing barrels on the working floor above. At this lower level the wall of the original, longer, north-eastern compartment of the higher corning house survives, continuing on beyond the corner of the shorter compartment on the floor above. There is, however, no joint where the wall of the original, shorter, south-western compartment would have ended, showing that this wall has been more extensively rebuilt.

The basement areas were much reduced in size during remodelling in 1928-9, when their function changed solely to the provision of access to the turbine which now occupied the central waterwheel-pit. Previously they were much larger, since the substantial stone blocks which now project from the inserted walls which are built up to and over them (Fig 70) are likely to have acted as supports for the vertical drive shafts of the 1863 glazing house. Each basement is entered through a narrow doorway in the wall facing the river: both doorways have external stone lintels and inner timber lintels, and are likely to have originated as part of the higher corning house. The ceilings over the corning-house basements, and of the 1863 glazing house, will have been of wood supported on timber beams, but during the remodelling of 1928-9, when they were reduced in size, new solid concrete floors which were overlaid with joists and floorboards

(see recesses in concrete for lost joists) were laid over the ground floor. The ceilings of the contemporary small basements have pairs of steel beams running north-east to south-west supporting flat central concrete panels and inclined outer panels (Fig 69). There is no accommodation for drive shafts rising up through these concrete panels, suggesting that power was delivered by a vertical shaft rising within the area of the waterwheel-pit and driving a line shaft at wall-head height.

Fig 70. Inside the reduced basement beneath the south-western compartment of the glazing house, showing the stone block incorporated within the rear wall and the inspection opening for the turbine occupying the waterwheel-pit. (NMR DP003531)

The original waterwheel does not survive. However, the side walls of the central wheel-pit have tall, opposed rectangular openings with stone lintels in which the waterwheel axle was formerly set; these are now blocked. Another blocked opening in the south-west wall of the wheel-pit, west of the axle opening, suggests that power take-off from the wheel may have been by ring drive, via a spur wheel, to a vertical shaft which then powered line shafts in both compartments. The wheel-pit was subsequently extensively altered to take a water turbine, although if a unit was installed as early as 1903, as documents suggest, then it is the concrete and steel fittings of its more powerful successor, installed as part of the remodelling of 1928-9, which survive (Fig 71). These take the form of an intermediate, flat-topped, concrete

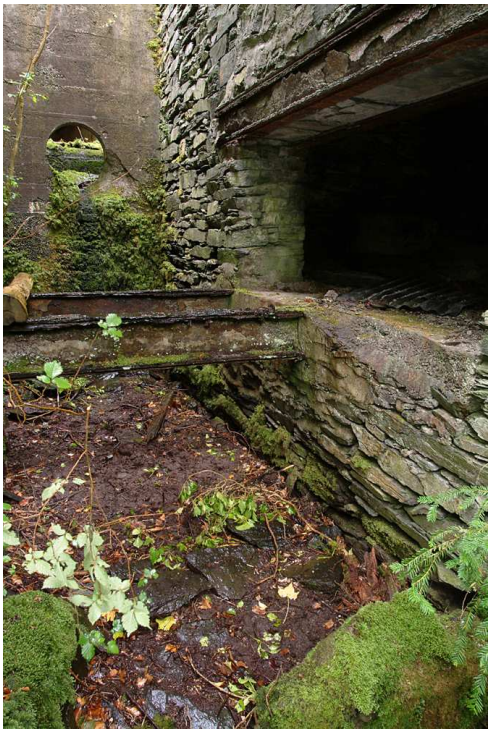


Fig 71. Two views of the glazing-house waterwheel-pit: a (left) looking north-west down the pit, showing the cross-wall for the turbine supply-pipe.(NMR DP003480) b (right) looking south up the pit, showing the joists for the turbine and the imprint of the discharge-pipe. (NMR DP006449)

cross-wall, set towards the upper end of the wheel-pit, which has a circular aperture for the supply pipe which fed water to the turbine. Steel joists across the wheel-pit supported the lost turbine, and curved shaping in the concrete base of a wide inspection opening created

in the south-west side of the pit indicates the line of its discharge pipe, the base of which was also supported by a low concrete cross-wall on the south side of the wheel-pit's mouth. A long iron shaft with a circular turning handle, set at a high level on iron brackets projecting out from the south-west wall of the wheel-pit, cannot have operated the turbine gate, and may therefore have engaged instead the gearing mechanism of the drive shafts. The handle was operated from the front (south-east) end of the pit.

Reel and Glaze House (buildings 55 and 56)

The reel and glaze house was sited towards the top end of the works, close to a westward bend in the river; it was also positioned near the sites of the 'earliest' expense magazines (this section above) which consequently had to be relocated when it was built. It was erected sometime between June 1861 - when the land on which it stood was leased by the company from the Bigland family (section 4.2 above, and Fig 5) - and June 1863, for it appears on the 1863 sale plan (Fig 6) and is also listed in the schedule to the accompanying indenture (section 4.2 above). As shown on this and subsequent map depictions, the reel and glaze house bridged a newly constructed leat running between the headrace and river, and comprised separate, unequal-sized, compartments north and south of a central waterwheel-pit. A breakwater is reported in 1894, intended to protect the waterwheel from damage when the river was in spate (HF LW/959/371), but at such times water still backed up in the tailrace causing a loss of power to the wheel (MMB, 26); map evidence shows the breakwater existed by 1888 (Fig 7). Since the 1926 factory plan (Fig 9) does not indicate the reel and glaze house as one of the stone-built danger buildings, it presumably comprised a timber and slate or metal superstructure on stone foundations.

Glazing was discontinued at the reel and glaze house sometime between 1926 and 1933/4 (most probably in 1931 – see below). It is likely that before this time glazing was carried on in the southern compartment and reeling in the northern, for the MMB (page 25) states that the four reels in the latter part of the building were rebuilt in 1932, whilst two new reels (?replacing earlier glazing barrels) had been installed in the southern compartment in 1931. This is also the implication of a little diagram of the layout of the house included on the May 1863 sketch, which shows four glazing barrels and four reels in line apparently south and north of the waterwheel-pit (HF LW/Misc/074, reproduced here as Fig 59). The same sketch states that the waterwheel was 14 feet in diameter by 6 feet wide (4.27m by 1.83m) and had thirty 'open sole' buckets; power was transmitted to the glazes and reels by bevel wheels on a transverse shaft which was itself turned by a bevel wheel connecting into a 'pinion and 2 boule wheels' on the shaft from the waterwheel. The MMB states that the two reels which replaced the glazing barrels in 1931 were manufactured and erected by the firm of T Dryden & Sons of Preston, and that by 1933/4 all the reels in the house were driven through bevel gearing with a sliding drive-wheel. This enabled reels to be stopped and started independently of each other; however, to do so, the waterwheel had to be stopped and re-started each time. In addition it is clear from the MMB that by 1933/4 the northern compartment of the house accommodated dusting as well as reeling; this had probably been so since 1875 (dust houses, this section below).

In 1863 the principal means of transporting powder to and from the reel and glaze house was reportedly by boat along the headrace (section 6.2.9 below), although the house also possessed road links to the stoves, magazines and dust house. Boating was probably discontinued following the construction of the internal tram system in 1869. According to the OS first edition 25-inch map surveyed almost twenty years later (Fig 7), the northern compartment was at that time served by a short spur leading off a tram line alongside the headrace, and the southern compartment by a spur coming off a second line routed to the rear of the building; both spurs ended at covered loading bays, the former at the far end of the south-east frontage, the latter in the centre of the south-west gable wall. Such an arrangement may well be linked to the conversion of the reel and glaze house in 1875 to accommodate dusting as well, for with this track arrangement corned powder could readily be brought to the glazing barrels in the southern compartment from both the low and high corning houses, while dried powder from the stoves and/or expense magazine no. 2 could be taken directly to the northern compartment where, certainly by 1933/4, the dusting machine was located.

As a danger building, the reel and glaze house would have been one of those set alight when the factory closed in order to remove powder residues; in the 1960s any upstanding ruins were presumably razed to the ground to help shore up the headrace to the hydro-electricity station. The principal survival is the waterwheel-pit, although the approximate extent of the southern compartment is visible as a shallow rectilinear depression (Fig 142). This depression suggests that each compartment may have had a suspended floor laid over stone foundations, with walling above floor level constructed from a flimsier material such as wood or metal sheeting. The foundation levels of both compartments were presumably infilled in the 1960s as part of the programme to shore up the headrace. The waterwheel-pit measures 2.07m across, broad enough to accommodate the 6-foot wide wheel reported in 1863; the fastenings for the axle mount also still survive on the northern side (Fig 21). The level of the base of the short leat leading to the wheel-pit indicates that the waterwheel was breast-shot; the base and sides of the leat are all lined in concrete, presumably dating from the 1928/9 modernisation of the works by ICI, but the pit itself and tailrace leading back to the river have walls of bare stone. The wheel-pit is crossed by two I-section steel girders marking the position of the bridge carrying the tram line which the historic maps show passed to the rear of the building; the course of this tram line west and north of the reel and glaze house can be followed as a series of earthwork cuttings and embankments which correspond exactly with the cartographic evidence. The breakwater reported in 1894 survives as a spit of large river cobbles extending out into the Leven.

Stove Houses and associated boiler houses (‘Stoves’)

Once glazed, gunpowder had to be dried to remove any residual moisture left over from incorporation and not removed by glazing. This was done at the stove or drying house. Lowwood seems to have possessed two stoves for much of its life, normally referred to as the lower (that is southernmost) and upper (northernmost) houses. Almost without question, the lower house is the original stove documented in 1799, while the higher stove existed by 1846. As each stove complex actually consisted of a stove house and a detached boiler

house in close proximity, the terms stove house and boiler house will here be reserved for the individual buildings, with 'stove' used to refer to the overall complex.

Both stoves stood adjacent to, but on opposite sides of, the headrace, about 60m apart. Although some gunpowder works employed gloom stoves well into the 19th century - in which the temperature of the air inside the stove was raised by an external fire heating a metal shield built into one wall of the building - early reference to the use of steam chests and boilers (section 4.2 above) shows that at Lowwood the safer method of running steam in iron pipes around the floor of the building (which first appeared in England *c* 1770 (Cocroft 2000, 35-6)) was used right from the start. Steam was generated in a boiler house separate from the main stove building in order to reduce the risk of sparks igniting the powder being dried. The lower stove house became redundant around 1928 when the introduction of improved glazing reels obviated the need for stoving of loose powder, although its boiler house seems to have been rebuilt to power a steam turbine blowing hot air sited in the former boiler house at the higher stove, whose stove house was now used exclusively for the drying of blasting cartridges.

Both stove houses appear to have been refashioned periodically, but since the new structures occupied the same sites as their predecessors and it is impossible to determine the precise extent of the rebuilding from map evidence alone, all phases are identified below and on Figs 132-41 by the numbers (46 and 47) ascribed to them on the 1926 factory plan (Fig 9). Both boiler houses were also remodelled from time to time, but the same caveats apply. The latter structures are unnumbered on the factory plan, but will here be labelled buildings 46a and 47a. A different sequence of numbers was in use at the works by 1933/4, and the MMB (page 35) refers to the higher stove house and boiler house as buildings 59 and 60.

Before the introduction of the internal tramway system to the works in 1869, there are documentary references to the headrace being used to transport powder by boat between the two stoves, the reel and glaze house and expense magazine no. 2. The evidence for this – both documentary and physical - is reviewed in section 6.2.9 below.

Lower Stove / Stove no. 1 (buildings 46 and 46a)

The earliest mention of the 'Lower Drying [Stove] House' by name is to be found on the 1846 plan (Fig 4), although the stove house almost certainly dates from 1799 for mention in the original lease of the company's right to construct 'a stove in … Biglandwood grounds' seems to be a clear reference to its site. Talk of it in 1859 as 'the old stove house' (this section below) - unless the term was used loosely - strengthens the argument. This, therefore, should be the stove which accommodated the leaky steam chest with which the company commenced powder production, and the Bateman and Sherratt boiler which replaced it in 1801 (section 4.2 above).

The 1846 plan shows that the lower stove consisted of two buildings - a stove house and a boiler house - set within a walled enclosure whose north-west side was defined by the headrace. The stove house is the L-shaped building which fills much of the south-west end of the enclosure, while the smaller, almost square, building at the north-east corner is a detached boiler house; a line between the two must represent the course of the steam feed-pipe. The outer walls of the two buildings formed integral parts of the enclosure wall. The

complex is next portrayed on the 1863 sale plan (Fig 6) which identifies it as 'Drying House No. 1'. The depiction implies that both buildings had been rebuilt or enlarged, for the stove house is now a full rectangle and the boiler house is not only larger but is shown with a chimney at its north corner. All of this ties in well with documentary evidence which states that in July 1859 the company had the intention to alter 'the old stove house' to accommodate a larger boiler and new chimney (section 4.2 above).

Later maps and plans of 1888, 1911 and 1926 (Figs 7-9) suggest that the form of both buildings changed little in subsequent years. However, this is at odds with information contained in an estimate sent to the company on 21 October 1911 for the cost of building a 'Proposed Drying Stove – 21ft x 15ft (inside)' (HF LW/959/389b), and it may be that the portrayal of the complex on at least the 1926 factory plan is anachronistic. Although EH has found no documentary evidence which indicates where this proposed stove was to be built or indeed that it was ever erected, field evidence shows that the lower stove house was at some point reduced to an internal length of 6.19m, close enough to 21ft (6.4m) to suggest it as the site. The estimate also contains references to 'Brick and Concrete Work'. There is now no visible trace of these materials at the lower stove, but the reference could easily be to features in the stove house interior which is now obscured by rubble. The reduced building appears to have been disused by about 1928, since Tyler (2002, 152) states that after the installation of modern glazing drums capable of removing far more of the residual water content, stoving of loose powder was discontinued. However, alterations were subsequently carried out to the boiler house, as indicated by a photograph entitled 'Lowwood. New boiler house & bridge for tramway. June 1929' (Fig 72) which shows the building had been extended, presumably to accommodate a larger boiler. The fact that the photograph also shows a steam pipe exiting the boiler house through the louvred vent above the doorway in the north-west gable wall and crossing the headrace, indicates that the reason for the improvement was because the boiler house was now used to send steam to the higher stove, whose own boiler house had been converted to accommodate a steam turbine blowing hot air (higher stove, this section below).

Fig 72. The enlarged boiler house at the lower stove, and the new tramway bridge across the headrace in 1929. (Patterson Collection, ©English Heritage.NMR)

As already stated, the lower stove house and boiler house stand within a walled enclosure beside the headrace. Although the 1846 plan shows a path leading to the enclosure from the track through the woods on the east side of the headrace, the main access was always from the main part of the gunpowder works via bridges over the headrace. The 1846 plan and 1863 sale plan both portray just one bridge, albeit in different positions (that shown on the

later plan may well be a misplot), but the 1888 OS first-edition 25-inch map (Fig 7) depicts two: one can be equated with that shown opposite the stove house in 1846, the other is oriented just north of the end wall of that building. Since the map also shows the tram line to the lower stove terminating at the edge of the path leading to the lower of the two bridges, it would appear that powder was offloaded from the bogies on the main works' side of the headrace to be wheelbarrowed across and into the stove house through a doorway directly opposite the bridge. In 1911, however, the OS second edition 25-inch map (Fig 8) indicates that this footbridge had been superseded by a bridge carrying a short spur from the original tram line diagonally across the headrace to the same doorway into the stove house. As the depiction of the bridges on the 1926 factory plan reverts to that on the first edition map, it would tend to support the suggestion made earlier (this section above) that the factory plan is in error in its portrayal of the stove complex. The 1929 photograph (Fig 72), however, together with Patterson's captioning of it, both indicate that when the boiler house was rebuilt in that year the diagonal tramway bridge was replaced by one which crossed the headrace almost square-on and was oriented on the open ground between the boiler house and former stove house. This ties in with earthwork evidence that the short tramway siding which both the OS maps and 1926 plan depict adjacent to the boiler house at the higher stove complex, was later extended as far as the lower stove (Figs 141 and 142). The new line was probably used to deliver coke for the boiler; the stove house may have become a coke store at this time.

The visible surviving structural elements of the lower stove are an L-shaped length of the boundary wall (which defines much of the complex's enclosure and incorporates elements of the south-east and south-west walls of successive stove houses), an intact boiler house and a short length of boundary wall between the boiler house and the edge of the headrace (Fig 73). The interior of the stove house is currently obscured by collapsed masonry. All standing walls, apart from those of the boiler house, were heavily overgrown prior to the EH survey, and ivy and other vegetation cover had to be cut away before investigation could proceed.

The stove house is represented by walls which belong to a succession of buildings. The earliest masonry should belong to the L-shaped stove house shown on the 1846 map (Fig 4), although only the south-east wall, and short south-west wall of the small southern outshot, survive (Fig 74): each is 0.6m thick and constructed of good quality coursed slate rubble with coursed-in quoins. The south-east wall also contains a blocked doorway 1.27m wide below the central window of the shorter, 1911, stove house which reuses much of its length (Fig 75). Cartographic evidence shows that the L-shaped stove house was remodelled as a larger, near square building between 1846 and 1863, and the south-west wall of the enlarged structure may survive as part of the present boundary wall: this wall is of smaller, poorer quality, stone rubble than the wall it butts up against (Fig 74), and close to the point where, on map evidence, the western corner of the enlarged stove house should have been located some 2.55m in from the edge of the headrace, it also thins back from 0.6m to 0.4m. The thinning back implies that the wall is not a reused boundary wall, but was newly built at the time of the stove house's enlargement. The final modification to the stove house may be dated to 1911 by association with the construction estimate. The south-east wall of the existing structure was dismantled as necessary at this time to create the corresponding

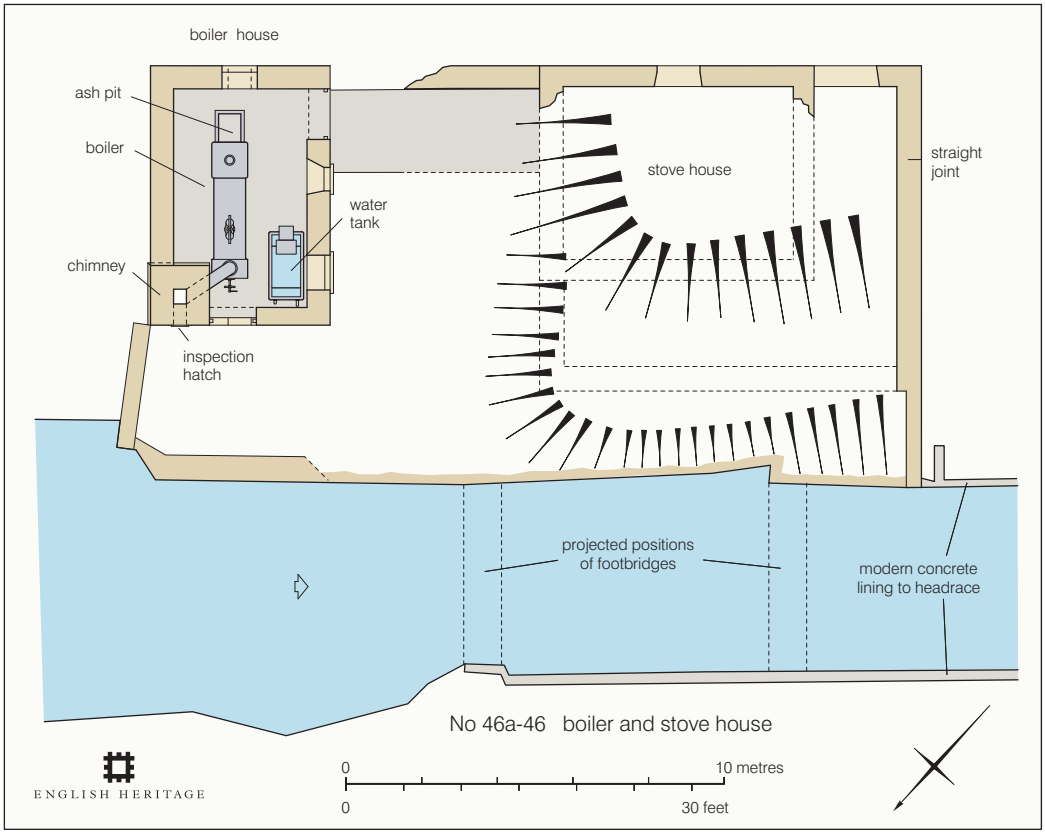


Fig 73. EH plan of the lower stove (see page xiv for key to conventions).

wall of the new building, whose corners lack noticeable quoins although they are visible as unequivocal straight joints with the adjoining masonry (Fig 75). Both corners return no more than a metre from the remodelled wall before disappearing beneath collapsed rubble, but clearly define a building 6.19m (20ft 3in) long internally - close to the 21 feet proposed in the estimate. There is no way of confirming from surface inspection whether the side walls extend the 15 feet recorded in 1911, but intriguingly the bulk of the rubble spread occupying the interior of the stove house is concentrated within 4.5m (15 feet) of the standing walls. A window with splayed reveals, but now without its head, occupies the upper part of the site of the former doorway in the centre of the wall. It is likely that there was a doorway in the north-

Fig 74. The lower stove, viewed from the south-west after vegetation clearance. (Ian Goodall, 2004)

Fig 75. The south-east wall of the lower stove. The corners of the 1911 stove house are arrowed. (Ian Goodall, 2004)

east end wall of the 1911 stove house (as indicated by evidence for a concrete path along the inside of the stretch of boundary wall between the wide doorway in the south-west wall of the boiler house and the ruins of the stove house), and possibly another in the north-west wall facing the headrace. The wide window which abuts the southern corner of the stove house (Fig 75) may be contemporary with the remodelling, as is the larger rubble visible along the top of the south-west wall beyond the straight joint, which is probably best seen as repair of masonry which was of some age. Both walls had been part of the earlier stove house, but after 1911 were reduced to the status of perimeter walling only.

The boiler house - recently restored by the Lake District National Park Authority - is a single-storey building, gabled south-east to north-west, with a chimney set within the north corner (Fig 76). It is constructed of stone rubble, and variations in the character of this masonry and of the quoins indicate that it is of more than one build. The earliest part is the south-east gable wall, which, up to the top of the window opening, is built with larger stones and is less regularly coursed than the walls of the rest of the building. Its quoins, in contrast to those of the other gable wall, are only marginally larger than the stones which make up the main body of the wall. The date of this early masonry is uncertain, but it is likely to be part of the boiler house shown on the 1846 map, and may belong to the original structure erected in 1799. The rest of the fabric of the boiler house, inside and out, is very different from this early masonry, and belongs to the major rebuild undertaken in 1929. The south-east gable wall above the window, both side walls, plus the north-west gable wall and chimney are all built of small coursed rubble, and the quoins to the gable wall - which are repeated up the tall square base and tapering shaft of the chimney - are substantial blocks of stone with a rock-faced finish with dressed back and tooled corners. The chimney, which is set into the north corner of the boiler house, has a projecting, square-sectioned band at the top of its tall base, and a square-sectioned shaft which tapers gently to a stone cap with a chamfered top above a plain base. At the bottom of the chimney a hatch in the outer, north-west face, just above ground level, enabled the flue to be cleaned; this has a cast-iron surround with a pair of hinge pivots which originally supported a cast-iron door, now lost. The remodelled boiler house (Fig 73) has two doorways, a double door at the east end of its south-west side wall, approached from the stove house by a concrete path and wide enough to enable the parts of a boiler and other equipment to be taken in and out, and a narrower door in the centre of its north-west gable wall. The interior is lit by three windows, one in the centre of the south-east gable wall and

Fig 76.
The 1929 boiler house at the lower stove, looking south-east from across the headrace.
(NMR DP003482)

two in its side wall facing the stove house, and there are also small, square, louvred vents close to the apexes of both gable walls. The doors, small-pane fixed-frame windows, louvers and the lintels over them are of wood, and all were renewed during the recent restoration. The sill of the east window is of slate, and is evidently an early survival, but the other window sills are of concrete. The gables both have squared ends simulating kneelers, but they and the masonry of the gable slopes are finished with a smearing of mortar, not with coping stones. The apexes of both gables, most noticeably that to the south-east, were repaired recently, and the roof covering of corrugated iron also renewed.

Inside, the walls of the boiler house are whitewashed. The timber lintels over the openings are all modern, as is the corrugated tin roof and the single central steel truss with three steel purlins on each side which supports it. This truss is a copy, in overall shape if not in the detailing of its individual components, of the truss which it replaced which lies discarded in a fragmentary and distorted state on top of the rubble inside the stove house. This earlier truss (Fig 77), which must

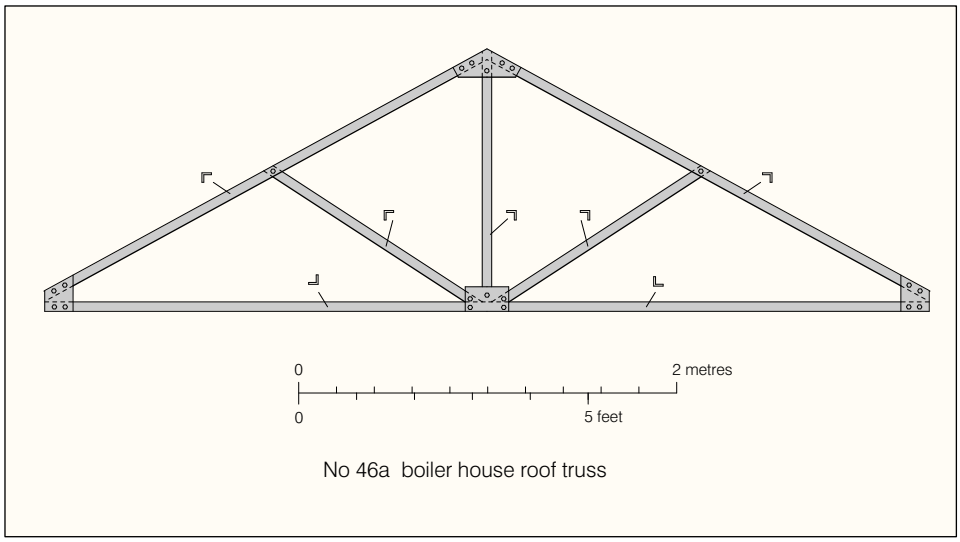


Fig 77. EH reconstruction of the discarded boiler-house roof truss (see page xiv for key to conventions).

date from the 1929 rebuilding, is triangulated and is constructed of individual lengths of angle-iron bolted together either directly or through shaped, flat-iron plates. It has the equivalent of a tie-beam, king post and diagonal struts up to rafters which support three sets of purlins on each side.

A stationary steam boiler still survives within the boiler house (Fig 78). This sits slightly off-centre, and butts up against the interior angle of the chimney which intrudes into the north corner of the building (Fig 73). The name 'ROBEY & CO LTD LINCOLN' plus the manufacturer's number 19420 are cast into the firebox door. The original order books for the firm of Robey & Co record that this boiler was manufactured in 1899 for one 'O Spe[…]' (information from Dave

Fig 78. Robey boiler no. 19420 inside the 1929 boiler house at the lower stove. The water tank is just visible at left of frame. (NMR DP003493)

Davies). It must, therefore, have been purchased second-hand by the Lowwood company sometime in the early 20th century, quite possibly in 1929 specifically for the rebuilt boiler house. The boiler, which stands over a brick-lined channel, has its firebox at its south-east end - well-placed for obtaining fuel through the wide doorway - a cylindrical, timber-lined boiler, and an exhaust chamber with a cranked flue which leads into the side of the chimney in the north corner. A water tank stands in the west corner of the boiler house. This is supported on a brick base, and pipes lead from it to the boiler. The 1929 photograph (Fig 72) suggests that it was replenished from the headrace using a portable pump.

The lower stove, standing as it did on the edge of woods on the opposite side of the headrace to the main gunpowder works, always had a stone boundary wall. Most of the walls of this enclosure originated as the walls of successive stove and boiler houses; a few, however, did not, and are simply lengths of boundary wall, built of coursed slate rubble. These comprise the thinned-back part of the south-west wall next to the headrace, the remnant of the wall between the stove house and the boiler house, and the short length of wall between the corner of the boiler house and the headrace. The first two lengths of wall do not survive to their full height and thus retain no coping, but the last is topped by irregular slabs of slate. The first length of wall is 0.4m wide and 2.55m long, while the second is 0.6m thick and extends 2.35m from the corner of the stove house to a ragged end, indicating that it must originally have extended as far as the boiler house. The third length of boundary wall (visible in Fig 72) is lower than the other two, and is of coursed small rubble similar in character to, and no doubt contemporary with, that of the masonry of the 1929 boiler house. It is offset from the north wall of the boiler house, although their corners touch, and runs at a slight angle towards the headrace.

The edge of the headrace which forms the north-west side of the stove enclosure is still retained by its original stone wall (Fig 73), although now capped in places by a fillet of cement; a slight kick-out in the face of the wall close to the south end of the complex probably marks the abutment for the lower of the two footbridges recorded on historic maps. The opposite side of the headrace was re-lined in concrete in the 1960s, and there is now no evidence for a corresponding abutment on the north-west side nor for the abutment to the tramway bridge recorded in 1911, although the presence of rails on the bed of the headrace suggests that the latter may have been an insubstantial construction perhaps similar to that built in 1903 to carry the tramway across the headrace at New Sedgwick (Dunn *et al* 2003, 116-17, figure 49). The water level in the headrace was raised at the same time as the sides were relined, and in winter when river levels are high, water can overtop the unraised original stone lining and flood the stove complex (Fig 76), even entering the boiler house.

Higher Stove / Stove no. 2 (buildings 47 and 47a)

The earliest direct evidence for the higher stove is once more the 1846 plan (Fig 4), which identifies a rectangular building next to the headrace as ‘Higher Drying House’. A second free-standing building close behind it is unnamed, but must be the boiler house; a line on the plan linking the two buildings presumably represents the course of the steam feed-pipe. A small projection on the front of the stove house, facing the headrace, interrupts the line of a road running between the higher corning house and ‘early’ dust house (buildings 50 and 80),

and must be a covered loading-bay; this suggests that the building was entered through a single, central, doorway at this time. Both buildings and the steam feed appear on the 1863 sale plan (Fig 6), labelled 'Drying Ho[use] no. 2'. The stove house appears wider than in 1846 and is depicted without its porch, whilst the boiler house seems larger and is shown with a detached chimney opposite its northern corner. Although the sale plan contains demonstrable errors (section 4.2 above), there is no reason to doubt its basic portrayal of these two buildings since very much the same footprint also appears on the OS first and second edition 25-inch maps surveyed in 1888 and 1911 (Figs 7 and 8). The only major difference is that these two later maps both depict the tramway installed in 1869 superseding the road (section 6.2.9 below), and once more show a small, central, covered loading-bay. The second edition map also portrays blast banks (here called BB3 and BB4) shielding either end of the stove house; a note on the 1926 factory plan (Fig 9) records that these were authorised by an amending licence dated 27 March 1884.

The stove house was remodelled after 1911, however, because the surviving structure is entered through doors at either end of its front wall. This could have happened before 1926 since the factory plan shows the building without its central loading-bay, but photographic evidence suggests the alteration rather dates from 1929 and was undertaken as part of ICI's general modernisation of the works. A photograph in the Patterson Collection (Fig 79), captioned 'Front of stove during reconstruction. June 1929' shows a pair of deep porches at either end of the front wall, extending out over the course of a new, but yet to be laid, length of tram line. The suggested date of remodelling is backed up by a second photograph (Fig 80), again taken in 1929 but this time depicting the rear of the stove house plus the boiler house, which shows that the boiler-house chimney had been demolished and that steam was being piped in from the direction of the lower stove complex. This ties in well with statements on page 35 of the MMB to the effect that by 1933/4, the stove house had been subdivided into two compartments plus an internal 'loading gangway' running the length of the building, with hot air supplied from a steam turbine situated in the

Fig 79. The front of the higher stove house during reconstruction in 1929. (Patterson Collection, ©English Heritage.NMR)

Fig 80. The rear of the higher stove house and heater house viewed from the west following reconstruction in 1929. (Patterson Collection, ©English Heritage.NMR)

former boiler house - all linked to the conversion of the building to the exclusive drying of blasting cartridges. Cartridges arrived at the stove direct from the cartridge-press house, and once dried were sent on to the cartridge-packing rooms to be wrapped and packed into boxes (section 6.2.4 below).

The roofless and semi-ruinous shell of the stove house still stands, although badly overgrown (Fig 81). The ruins were not cleared of undergrowth and fallen trees prior to investigation by EH. It was, as the 1929 photographs indicate, a single-storey building, gabled to the north-east and south-west, and built of slate rubble with limited use of quoins at its corners. It is rectangular in plan (Fig 82), has walls 0.6m thick, and measures 11.07m by 5.86m internally. The front (south-east) wall, which faces the headrace a short distance away, stands 2.5m high to its eaves, but the rear wall has fallen outwards and barely survives above its bottom courses. The roof, shown as felted in 1929 (presumably replacing a slated precursor), has gone completely. Despite its poor condition, however, the building retains considerable evidence of two main phases of use. This structural evidence has been combined with other evidence on how powder was transported to and from the building (section 6.2.9 below) to define three principal stages in the development of the stove complex as a whole. These phases are illustrated as a series of perspective reconstruction drawings (Fig 83).

Fig 81.
The interior of the higher stove house, viewed from the north-east.
(NMR DP003449)

As first built, the front wall of the stove house had a central doorway shielded by a covered porch extending out over the roadway; this was flanked by a pair of windows with splayed reveals. The south-west gable wall had two openings: one a slightly off-centre window which probably served as a louvred vent; the other, at the base of the wall next to the south corner, an opening of unknown use, 0.6m wide by 0.8m high, with an inclined projecting slate lintel. The base of the window was originally lower than it is now. The north-east gable wall was blind, and since the rear wall has fallen nothing is known about it except that it must have contained at least one opening through which steam was piped in from the boiler house. Documents suggest that at this time the principal means of transporting powder to and from the stove was by punt along the headrace (section 6.2.9 below).

Punting was discontinued in 1869 when a tram system was installed at the works. A tram line was laid approaching the stove house from the north and curving to pass in front of the building before continuing along the side of the headrace as far as the lower stove. Blast banks were reportedly authorised in March 1884 (this section above), but do not appear on the OS first edition 25-inch map surveyed in 1888 (Fig 7) - presumably because they fell outside the recording policy operated by the OS at that time rather than because they had still to be erected. Both blast banks (BB3 and BB4) survive in reasonable condition, although

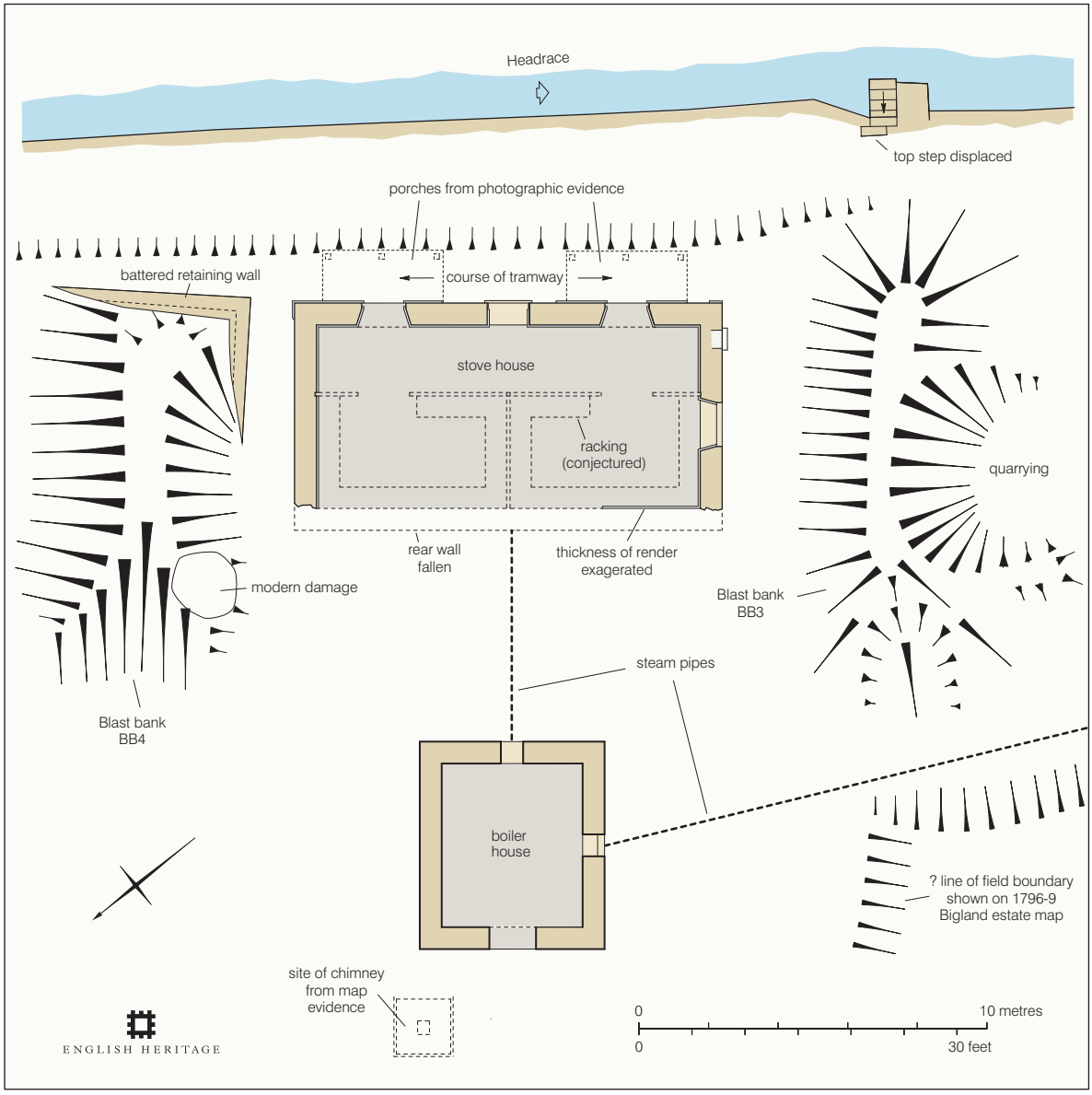


Fig 82. EH plan of the higher stove (see page xiv for key to conventions).

badly overgrown and in places quarried away. The north-east flank of BB4 appears originally to have been faced with river cobbles, whilst the end nearest the headrace is retained by a near-vertical stone-rubble wall in order to allow the tramway to pass close to its foot and on in front of the stove house. There is no evidence that the other bank was similarly retained; it seems now to have slumped forward slightly across the line of the tramway's continuation to the lower stove (Fig 82). The factory plan (Fig 9) suggests that by 1926 an additional short blast wall (here called BW12) had been erected adjacent to the headrace opposite the end of BB4. Its purpose is unclear: from its position it seems to have been designed to protect the steps at the side of the headrace used in connection with transporting powder by punt, but these steps were in all probability disused by this time. No physical evidence for the wall survives on the ground.

In 1929 (if not before) the existing central front door of the stove house was converted into a window and the flanking windows converted into doorways. The lower half of the original doorway was blocked and a concrete sill inserted, while the walling below the windows was

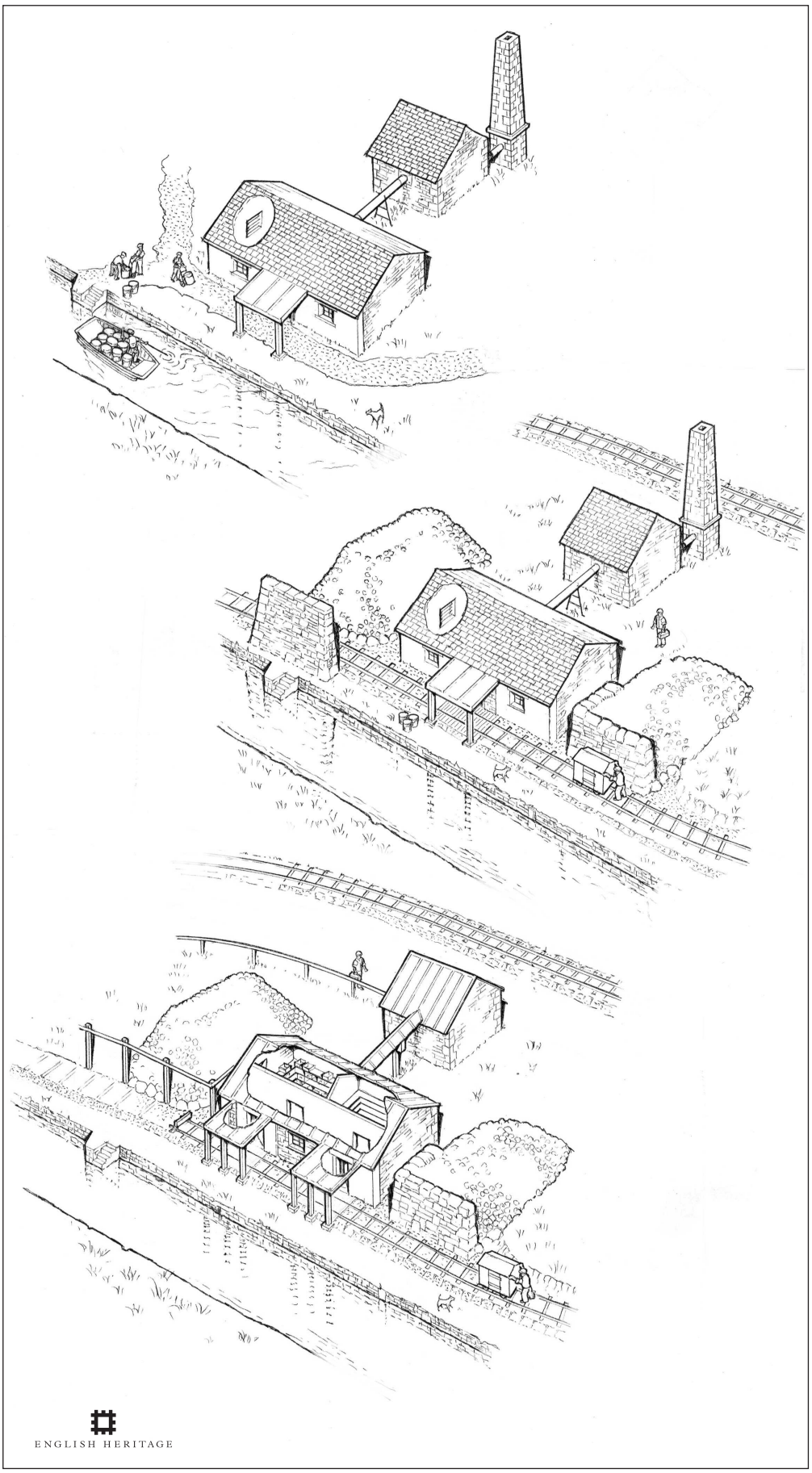


Fig 83. EH reconstruction drawings showing the principal stages in the development of the higher stove

cut out, resulting in them both having full-height splayed sides which demonstrate their origin as windows. The central porch was replaced by new porches outside both doors, each supported by three timber posts on concrete blocks. In the south-west gable wall, the bottom 0.88m of the off-centre window was blocked and a sill inserted at the higher level, and the opening in the base of the wall next to the corner also blocked. Finally, lengths of the front wall close to the three openings, and the whole of the interior, were finished off with a screed of cement render. Internally, the render - which can in places be seen to have a base coat and a top coat - was applied to a height of *c* 2.2m and ran around the reveals of the windows and down the sides of the two doorways. Although this was done primarily for reasons of safety, it has had the effect of masking the inevitable irregularities caused by interventions in rubble walling. From the combined evidence of the MMB (page 35) and the surviving structure, it is clear that the doorways gave access into a loading gangway and thence into two stove compartments. There is now no evidence for the partition which divided the compartments, but the MMB states that this was formed of wood lined with Uralite; the ceiling was formed from the same material, while the floors were concrete and timber. Each compartment is noted as measuring 12 feet by 18 feet by 7 feet 3 inches high (3.66m x 5.49m x 2.21m), indicating that the dividing partition must have been 4 inches (0.1m) thick. If a partition of similar thickness separated the compartments from the internal gangway, the latter would have measured a little less than 7 feet (2.13m) wide, as rebates in the internal render on the two gable walls confirm. Each compartment was reportedly fitted with wooden racks which accommodated 80 timber-framed, canvas-bottomed, drying trays. The MMB also records the presence of ventilation holes at the back of each rack: these must have been located in the lost rear wall, and are presumably to be equated with apertures visible on Fig 80.

After 1929 the tram line must have terminated at the higher stove. This is indicated both by the 1929 photograph of the front of the building (Fig 79) which shows the ballast for the track bed confined to the length of the building, and by earthwork evidence of another tramway to the rear of the building (Fig 142), which the historic maps (Figs 7-9) all depict as a short siding terminating immediately after the boiler house but which the field evidence shows must have been extended to form an alternative, direct route to the lower stove complex sometime after 1926.

Heat for the stove house was provided from a free-standing boiler house built some 5.8m to the rear. This building (no. 47a) - which was in use as a builder's store at the time of survey - is in generally good condition, and apart from a new roof seems to survive largely in the form it achieved in its final phase (Fig 84). It is a rectangular building, some 5.3m by 5.9m externally, gabled to the north-east and south-west and constructed of slate rubble with a few good quoins. The present

Fig 84. The front of the boiler/ heater house (building 47a) at the higher stove , now used as a builder's store. (NMR DP003448)

roof, which is of felt held down by laths, is a direct copy of that existing in 1929 (Fig 80), but in earlier periods the roof was presumably slated. Entry into the building is through a moderately-wide doorway with a renewed timber lintel in the front (north-west) wall, and there is a small window in the south-west gable wall. A wide but shallow slot part way up the rear wall must have taken the pipe which originally carried steam to the stove house. Photographic evidence (Fig 80), however, shows that in 1929 this pipe was replaced by trunking which emerged through the roof at mid-slope level, protected from the weather by its own felted awning; page 35 of the MMB records that the trunking was manufactured from galvanised iron. Part of the trunking or pipe survived in situ in the 1990s when photographed by Mike Davies-Shiel (Fig 85), but was presumably removed when the roof was renewed.

Fig 85.
The rear of the heater house (building 47a) in 1991.
(Davies-Shiel Collection, copyright reserved)

According to Mike Davies-Shiel (personal communication), who saw inside the building in the 1990s, steam was latterly generated by a Robey stationary boiler, manufacturer's no. 29946 or 29948. However, as the Robey company's order books record that boilers bearing these numbers were delivered in 1910-11 to, respectively, the Brightside Foundry & Engineering Co and Northern Rubber Co (information from Dave Davies), whichever one ended up at Lowwood must have arrived there second-hand, presumably shortly after World War I. There is no evidence for the make or type of boiler in use in earlier periods. The Robey boiler was not in use for long at Lowwood, however, as the photographic evidence (Fig 80) suggests that the method of heating was altered in 1929 at the same time as the stove house was refashioned. The photograph shows that the boiler-house chimney had been demolished (the factory plan shows it still in existence in 1926), indicative of steam no longer being generated within the building; instead, steam was evidently brought from the direction of the lower stove via a pipe which entered the boiler house below the window in the gable wall. Perhaps most tellingly, the caption accompanying the photograph refers to the building not as a boiler house but as a 'Heater House'. This interpretation of the evidence is supported by the MMB (page 35), which records that in 1933/4 heat for the higher stove was provided by a 'Keith Blackman plant' consisting of a 0.5bhp (0.37kW) steam turbine direct coupled

Fig 86.
The Blackman plant in the heater house (building 47a) at the higher stove in 1991.
(Davies-Shiel Collection, copyright reserved)

to a fan blowing cold air across steam-heated tubes enclosed in a sheet-iron casing. EH did not see inside the building during investigation, but according to Mike Davies-Shiel and Ron Mein (personal communication), the Blackman plant still survives *in situ* within the building (Fig 86), although the Robey boiler does not.

Stove and heater houses appear to have had the benefit of electric lighting by 1929. Both early photographs (Figs 79 and 80) show a series of timber posts supporting a rail, attached to which is a power cable. This cable approached the complex along the side of the headrace, and turned to run along the south-east gable and rear walls of the stove house before entering the heater house by way of the steam-pipe support between the two buildings.

Dust and Dust-Charge Mixing Houses

After stoving, loose powder was sent to the dust house for the removal of any remaining under- and over-sized grains. There seems to have been at least three dust houses at Lowwood over the 136 years the factory was in production. All three buildings stood on different sites, although after 1880 dusting was carried out not in a separate, dedicated building, but in the reel and glaze house thereafter called the reel, glaze and dusting house, and later the sizing, dusting and reeling house. Although not known as such during their lifetimes, the first two dust houses will here be referred to as 'early' and 'later'. There is no firm evidence that either was mechanically powered, but the reel, glaze and dusting/sizing, dusting and reeling house which succeeded them had its own waterwheel.

The early dust house was superseded by the later dust house in 1861. Although the early dust house remained standing for a year or so, it was probably destroyed in, or demolished following, the big explosion of January 1863. The later dust house was itself superseded sometime before 1880, and turned into the heading-up house. The latter is identified as building 49 on the 1926 factory plan (Fig 9), while the reel, glaze and dusting house appears on the same plan as buildings 55/56: these numbers have therefore been retained for use in the present report. By 1933/4, however, both buildings had been allocated new numbers: the later dust house/heading-up house had become building 63, the reel, glaze and dusting house (by this time re-christened the sizing, dusting and reeling house), buildings 68/69 (MMB, 43 and 24). For the purposes of the present report, the early dust house is referred to below and on Figs 132-5 as building 80, although in its day it appears to have been known as building 6 (HF LW/1863/005).

Between 1875 and sometime prior to 1926, the dust from the dusting process seems to have been stored in a dedicated dust-charge mixing house. This building is identified as building 51 on the 1926 factory plan, which is therefore also the number used for it in the present report.

'Early' Dust House (building 80)

The earliest evidence for the existence of a dust house at Lowwood is the 1846 plan (Fig 4), which shows a 'Dusting House' located adjacent to the river in the approximate middle of the works. Its date of construction is unrecorded, although it is quite possible that it existed as early as 1799. This early dust house was replaced by a newbuild successor (the 'later' dust house) on a different site in November 1861 on account of the erection of the low press

house nearby (this section above); the building was then downgraded to 'an empty cask and heading-up shop' until the explosion of January 1863 (HF LW/1863/005) when it was presumably either destroyed or demolished to make way for the relocated low press house mark II. There is no direct evidence for how the dusting machinery was driven at this time, but the location of the house on or close to the projected line of the outfall of the sawmill leat raises the possibility that it was in some way water-powered (compare Figs 132-5).

EH found no structural trace of the building during field investigation. The site is now occupied by the remains of the low press house mark II.

'Later' Dust House (building 49)

The 1863 sale plan (Fig 6) shows the new ('later') 'Dust Ho[use]' in an isolated position towards the top end of the works, some 35m north-east of the glazing-house leat. As stated above, it commenced operation in November 1861. However, it was disused for dusting by 1880, at which time dusting was reportedly being carried out (illegally) at the reel and glaze house - and probably had been since 1875 (this section below). After this date the later dust house was converted into a packing/heading-up house ('final' packing house, this section below).

The 1863 sale plan shows the later dust house as a rectangular building, entered through a doorway in the south-east gable wall where the plan depicts a small projection - presumably a covered loading-bay. The fact that the 1926 factory plan does not show the structure as one of the works' stone-built danger buildings indicates that it was most likely of timber construction. (For discussion of alterations and additions to the form of the building post 1875 when it ceased to be a dust house, and of its surviving physical remains, see 'final' packing house, this section below).

Reel, Glaze and Dusting / Sizing, Dusting and Reeling House (buildings 55 and 56)

As already stated, the reel and glaze house had been illegally converted before 1880 to accommodate dusting also. The company received a written reprimand for this on 31 May 1880 from Major Majendie, an HM Explosives Inspector, and instructed to apply for an amending licence so that the building could be expressly authorised for all three functions (HF LW/959/032). His instruction was obviously obeyed, for the key to the 1926 factory plan (Fig 9) shows the building duly designated as the 'Reel Glaze & Dusting House'. It is probable that dusting had transferred to the reel and glaze house as early as 1875, for the same letter implies that what had until then been the packing house became a dust-charge house in that year; the implication is that the old (later) dust house became a packing house at the same time ('final' packing house, this section below).

The reel, glaze and dusting house consisted of two separate timber buildings (or compartments) either side of a central wheel-pit (glazing and reel houses, this section above). It seems unlikely, however, that the action of dusting was spatially segregated from reeling and glazing. This is certainly the way the house operated in 1933/4 (by which time it was no longer used for glazing, and was known as the sizing, dusting and reeling house), for the MMB (page 24) states that one compartment then contained two reels, the other (probably the northern compartment) four reels and a combined dusting/sizing machine.

The latter machine consisted of a hopper feeding a rotating, sloping, dusting reel which allowed under-sized particles (locally called 'pin dust') to pass through and fall to the floor. The remaining powder passed through a separator made up of a nest of three sieves of diminishing mesh size within a wooden frame; over-sized grains ('chubbins') were retained by the first sieve, while the other two caught grains of the required sizes. The frame was agitated by two vertical crank shafts revolving at 65 rpm, with material conveyed between the hopper and dusting reel, and dusting reel and separator, by elevator bucket belts. All moving parts were driven from the central waterwheel (MMB, 24 and 26-7). In 1933/4, the pin dust was swept up into barrels and apparently returned straight to the incorporating mills where a spadeful or so was added to each green charge as it was placed in the incorporating pan (MMB, 6), but between 1875 and sometime before 1926 the pin dust seems to have been stored temporarily in a dust-charge mixing house (this section below).

Very little now survives of the sizing, dusting and reeling house, which would have been one of the buildings cleansed by fire in 1935 when the factory closed. The ruins were presumably further flattened in the 1960s when the headrace was heightened for the hydro-electricity station. The surviving physical evidence for the building – principally the central waterwheel-pit - has already been reviewed under reel and glaze house (this section above).

Dust-Charge Mixing House (building 51)

A report on an inspection of the works carried out by Major Majendie, HM Explosives Inspector, on 31 May 1880, records that in 1875 building 51 (which had been the 'later' packing house) was converted into a dust-charge house (HF LW/959/032). The function of such a building is not altogether clear, but it most likely acted as a temporary store for pin dust (under-sized grains emanating from the dusting process) prior to the dust being re-introduced to an earlier stage of the manufacturing cycle to be reprocessed. The building was disused, however, by 1926 when the key to the factory plan (Fig 9) describes it as the 'Dust Charge Mixing House'. There is no evidence that there was ever a dust-charge house at Lowwood before 1875. A description of the physical form of the building is included as part of the discussion of the later packing house (this section below).

Packing Houses and associated buildings

Once dusted and sized, gunpowder was ready to be weighed out and packed into barrels for sale. Both operations were carried out in the packing or heading-up house. (Heading-up refers to the closing of the barrels, and a heading-up house is therefore simply a synonym for a place where loose powder was packed). Before the Explosives Act 1875, powder loose-packed into barrels was really the only form in which gunpowder was sold. After the Act, powder was also marketed pre-formed into solid blasting cartridges; these were sold by the box. Cartridge packing, however, was a totally different process to loose packing and was normally carried out in a separate building, although at Lowwood it is likely that for a short while prior to the construction of the cartridge-packing rooms between 1884 and 1886 (section 6.2.4 below) cartridges were boxed at the packing house.

Three loose-packing houses are known to have existed at Lowwood: all stood on different sites, and succeeded each other. Although not known as such during their lifetimes, the

three will here be referred to as the 'early', 'later' and 'final' packing houses. The early house existed by 1846. It was superseded *c* 1861 by the later house, at which time the early building was downgraded to a store. The later packing house was itself converted in 1875 into a dust-charge house; packing then transferred to what had formerly been the dust house. The three buildings are all recorded on the 1926 factory plan (Fig 9) as buildings 43, 49 and 51, and the same numbers have therefore been used for them all on the phase diagrams (Figs 132-41) in the present report. However, by 1933/4 the final packing house had been renumbered as building 63 (MMB, 37 and attached sketch – the latter reproduced here as Fig 88). The MMB (page 39) also records that at that time the final packing house was staffed by a mixed complement of men and women.

In 1863 the later packing house is listed in apparent association with a boiler house, numbered building 52 on the 1926 factory plan although with a note to say it had by then been demolished. The possible function of this boiler house is discussed below. By 1911 the final packing house also had an attendant empty-cask store adjacent to it, identified as building 49a on the factory plan. An unnamed building on the 1863 sale plan which stands in a similar relationship to the early packing house may have performed the same function, but in the absence of specific evidence it will be described in section 6.2.7 below (building 43a).

'Early' Packing House (building 43)

The earliest evidence for the existence of a packing house at Lowwood is the 'Packing Room' shown on the 1846 plan (Fig 4) close to the river bank between the lower corning house and early dust house. The building was probably erected when or shortly after the works opened in 1799, although this cannot be proven. The plan portrays the building as a rectangular structure with a small projection, probably a porch or covered loading-bay area, indicating it was entered by a door central to the south-west long wall. A much smaller, almost square, building immediately north-east of the house is of unknown function, but was probably in some way associated – perhaps as a store for empty casks (building 43a, section 6.2.7 below). Packing transferred *c* 1861 to a new building located further to the north-east (the 'later' packing house, this section below), but the 1863 sale and 1926 factory plans (Figs 6 and 9) both indicate that the old house was not demolished, merely downgraded to a store.

EH found no trace of this building on the ground. Indeed the field evidence suggests that the building was probably demolished before the works closed, for the site indicated by the map and plan evidence lies across two broad terraces (Fig 142) which seem to have been created to provide access to the nearby lower corning house mark IV, erected in 1928.

'Later' Packing House and ?associated boiler house (buildings 51 and 52)

The position of the later packing house is recorded by the 1863 sale plan (Fig 6), which portrays a building close to the reel and glaze house at the top end of the works as 'Heading up Ho[use]'. The heading-up house is described as 'new' in the schedule to the accompanying indenture (section 4.2 above), and indeed it cannot have been more than two years old for it stood on land only leased by the company in June 1861 (section 4.2 above and Fig 5). Strangely, the schedule contains a separate listing for a 'packing shop and boiler house', but this would seem to be a duplicate reference to the heading-up house as the sale plan

depicts a boiler house (building 52) only a short distance north of the latter. Whether the two buildings were functionally associated – and indeed if so, why a packing shop/heading-up house needed a boiler house - is unclear, but the packing house at the New Sedgwick gunpowder works apparently contained a small stove within the building, which Dunn has suggested was used for melting paraffin wax for waterproofing the calico bags that lined the barrels (Dunn *et al* 2003, 77). Building 51 remained in use for packing until 1875, when it was converted into a dust-charge mixing house instead (this section above). Building 52 is marked on the 1926 factory plan (Fig 9) but with a note to say that it had been demolished. As the building does not appear on either the OS first or second edition 25-inch maps (Figs 7 and 8), it is possible that it had actually been demolished before 1888, perhaps shortly after 1875 when the need for it ceased following building 51's conversion to a dust-charge mixing house.

Map evidence suggests that the plan of building 51 changed little if at all from the time it was erected down to closure of the works in 1935. It was essentially rectangular, apparently entered through a doorway slightly offset from the middle of the south-east long wall as is suggested by the small porch or covered loading-bay shown by the two OS map editions. The 1926 factory plan also records that the walls were of stone; the roof was presumably covered in slate. Both the 1863 sale and 1926 factory plans show building 52 as a small building only *c* 4-5m square.

As a former danger building, building 51 was most probably one of those cleansed by fire in 1935. No surface trace which may definitely be ascribed to it was found during survey by EH: a small sunken platform containing stone débris was identified close to the site depicted by the maps and plans, but it probably lies just outside the position of the north-east gable wall. Possible interpretations of the latter feature are discussed further in section 6.2.10 below (unidentified features). Likewise no trace was found of building 52, but the position indicated by the cartographic evidence equates to an area of steeply-sloping river bank which now supports thick tree and ground vegetation.

'Final' Packing House and associated empty-cask store (buildings 49 and 49a)

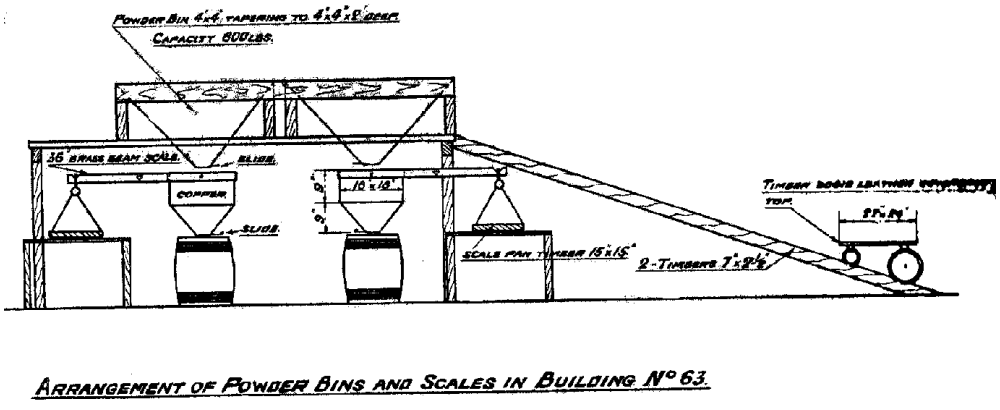
The earliest direct reference to building 49 being used for packing is the 1926 factory plan (Fig 9), whose key describes it as 'Heading-up-House'. However, given that the previous packing house had been converted into a dust-charge mixing house as far back as 1875 ('later' packing house, this section above), it seems likely that by the time of the plan the building had been used for packing for some 50 years already. It had been built originally as a dust house.

As previously stated ('later' dust house, this section above), building 49 was essentially rectangular in plan and is likely to have been of timber construction. The 1863 sale plan (Fig 6) also suggests it was built originally with only a single entry point: a doorway in the south-east gable wall, convenient for access from a track running along the building's south-west side. An entrance in this position would also have been well-placed when the works tramway was installed in 1869 for a branch followed much the same route as the existing track (information recorded on the 1926 factory plan). However, the 1926 factory plan also records that in 1883/4 this branch of the tramway was lifted and rerouted further to the north, and a

new spur laid on the opposite side of the building. The revised track arrangement is confirmed by the OS first edition 25-inch map (Fig 7), which also records that the spur terminated at a new entrance into the building close to the northern corner; once more, the latter was protected by a porch or covered loading-bay. By 1911, a companion building had also been erected immediately south-west of the packing house - which the key on the factory plan states was for the 'storage and unheading of empty barrels' - and a new tramway branch laid in the space between the two (Fig 8). Photographic evidence (Fig 87) shows that the walls of this latter building (no. 49a on the factory plan) were constructed of timber or metal-sheeting beneath a segmental-arch corrugated-iron roof; it was lit by three small, glazed, windows in its south-west long wall, each with small panes, with presumably two more windows and a doorway in the opposite side facing the packing house. The gable ends were blind.

Fig 87.
The empty-cask store (building 49a) servicing the 'final' packing house, photographed in 1969. (Palmer Collection, copyright reserved)

The MMB (pages 37-41) contains a description of the packing process carried out in building 49 in 1933/4. Powder arrived in tubs on tramway bogies from both the glazing house and the sizing, dusting and reeling house. These were offloaded onto another, specially adapted, wooden bogie which had different-sized wheels on each axle so that the body of the bogie remained horizontal as it was pushed up a ramp leading to a platform. The powder was then fed into two tapered, wooden hoppers suspended below the platform, each of which had a slide at its base. When these slides were withdrawn, powder was allowed to fall into a copper container which formed one end of a set of brass beam-scales situated beneath the slides. Each container also had a removable slide at its base, which allowed the weighed powder subsequently to run out into cotton bags positioned over empty powder barrels. The bags were then tied with string, before the head of the barrel was fixed in position and the barrel tipped on its side and removed to the store magazines in another tram bogie. A drawing of the plant so described is included in the MMB, and reproduced here as Fig 88.



Arrangement of Powder Bins and Scales in Building N° 63.

Fig 88.
Machinery employed in the 'final' packing house in 1933/4, as illustrated in the Manufacturing Method Book (MMB). (Patterson Collection, ©English Heritage.NMR)

Powder was weighed out into 5 lb, 10 lb, 18 lb, 20 lb, 25 lb, 50 lb or 100 lb bags (2.27-45.36kg) as required. In the case of blasting powder, both bags and barrels were stencilled before they were filled. Powder destined to be made into cartridges, however, was simply poured into barrels in an unbagged state, and the barrels closed temporarily for removal to the magazines until needed by the cartridge-press house (section 6.2.4 below).

As a danger building, the packing house would have been one of those burned down when the factory closed in 1935. No trace now survives of the superstructure, which ties in well with the evidence for it having been of timber. However, a concrete floor does survive, albeit mostly obscured beneath leaf mould, ivy and scrub trees. On the visible evidence - which is limited to the edges of the structure – the floor comprises a series of concrete slabs approximately 0.3m wide laid 0.1m apart. It is unlikely to date from when the packing house was first erected, however, and was most probably inserted into the building at some point in the 20th century. Concrete floors of similar design exist at the low press house, and in the glazing-house loading-bay (this section above); the latter can be dated with a reasonable degree of confidence to 1928. Traces of a small concrete machine base are evident under the ground vegetation close to the north-west gable end of the packing house, although no sawn-off metal holding-down bolts are apparent. Because it was a non-danger building, the attendant empty-cask store would not have had to be burned down in 1935. It was still standing in 1969 (Fig 87); however, it has since vanished and EH investigation uncovered no trace of it.

Store Magazines

Under the Gunpowder Act 1772, gunpowder, once manufactured, had to be removed as quickly as possible to magazines located in remote places, whose sites had been approved by local Justices of the Peace. The Act also stipulated that such ‘powder’ magazines had to be constructed in brick or stone (Cocroft 2000, 28). The legislation was tightened by subsequent Acts of 1860 and 1875: the first laid down that what it termed ‘store magazines’ for the keeping of finished powder, had to be at least 140 yards (128m) distant from any other building where gunpowder was manufactured or stored, and also had to be fitted with a lightning conductor (Public Statutes General 1860, 616-17); the second set up a completely new licensing régime for what were now designated as ‘factory’ magazines, which required all such sites to be approved by the Secretary of State at the Home Office, advised by the newly created HM Explosives Inspectorate (Public Statutes General 1875, 146-53).

The company’s first store magazine stood in Roudsea Wood, on the shore of the Leven estuary, and was authorised by the local Justices in October 1798. A second magazine was constructed here in 1836. By 1858, however, as the company began to send its powder by rail as well as ship, these two magazines were found to be inconveniently situated for rail shipment, and plans were drawn up to erect a new magazine closer to the works in ‘Busky field’; this was operational by 1861. Between 1886 and 1888 a fourth store magazine was also constructed on the opposite bank of the river, described in 1926 as ‘Factory Magazine’; it was used to store boxes of blasting cartridges. The two Roudsea magazines may have been largely abandoned by the end of the century.

Only the last of these four store magazines is depicted on the 1926 factory plan (Fig 9), which lists it as building 60. The area covered by the plan does not extend out as far as the Busky magazine, but the fact that there is no building 1 listed in the key suggests that this number was allocated to this magazine, which is therefore the number used for it in the present report. Likewise, the factory plan does not list the Roudsea magazines, but for present purposes they are listed on Figs 132-9 as buildings 83 and 84; they will also be distinguished from each other in the following description by use of a shorthand title utilising their year of construction.

The '1798' and '1836' Roudsea Magazines (buildings 83 and 84)

Roundsea (*sic*) Gap was approved as the site of the company's first store magazine by Justices sitting in Quarter Session at Lancaster on 2 October 1798 (section 4.2 above). The company subsequently invested in a second magazine situated some 124m to the south-west within Roudsea Wood, erected in September 1836 (Tyler 2002, 116). Both buildings appear on the OS first edition 6-inch map (Ordnance Survey 1851), and are annotated as 'Powder Magazine[s]'. The later magazine would also have had to be authorised by the Justices, but EH has not traced the judgment. Rather than erecting a purpose-built magazine from scratch, however, field evidence suggests that the company converted an existing bark barn (here called the 1836 magazine).

Both Roudsea magazines were less heavily used after *c* 1861 when a new magazine was constructed at Busky. This reflected a switch in emphasis on the part of the company from sea to rail as their preferred method of gunpowder shipment. However, the decision was as much a matter of necessity as taken on the grounds of cheaper cost, for the completion of the railway viaduct across the Leven estuary in 1857 was causing the traditional shipping channels upstream of the viaduct to silt and alter course. In 1879, the company even considered building a pier 200 yards (182.2m) long out into the river at Roudsea to facilitate continued use of the magazines there regardless of the state of the tides, but the proposal came to nothing. Although still operational in 1886, it is likely that both magazines were increasingly little-used thereafter (section 4.2 above).

The 1836 magazine is now ruinous, while the 1798 magazine has been converted into a summerhouse with a new doorway, fenestration and chimney stack. The field remains of both buildings were examined by RCHME/EH archaeological investigators in January 1994, and again by a team of architectural investigators in January 1999, as part of a project looking at the iron and related woodland industries of Furness; the resulting records were deposited in the NMRC in Swindon. Neither building has been looked at afresh for the present report, but the hitherto unpublished architectural record (Fig 90) of the 1798 magazine (NBR no. 95781) – which was examined, post-conversion, from the exterior only - shows that it was a small, rectangular, building, measuring *c* 6.6m by 5.2m internally, with walls formed of limestone quoins and roughly-coursed slate beneath a double-pitched roof. It was entered through a doorway in the north-east gable wall, and had a pair of staggered, 'rat-trap', ventilators in the north-west long wall. However, EH has since been shown a slide of the magazine (Fig 89) taken in 1969

Fig 89.
The entrance to the '1798' Roudsea magazine in 1969 prior to conversion to a summerhouse. (Palmer Collection, copyright reserved)

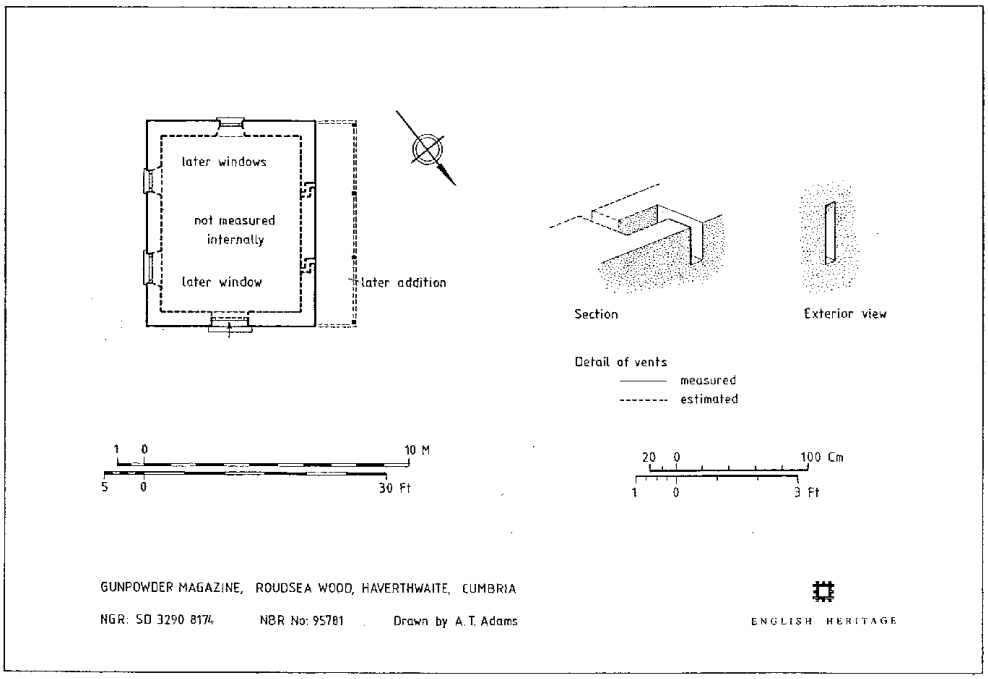


Fig 90. EH archive plan of the '1798' Roudsea magazine. (NBR No. 95781, ©English Heritage.NMR)

before conversion, which reveals that the doorway was protected by a small enclosed porch. Although the porch itself was already lost in 1969, the scar shows that it was a timber construction beneath a double-pitched roof, and that it was rendered internally; it is likely that it was also fitted with an outer door (see below). In 1969 the magazine still retained its original inner door: a notice attached to the inside stated 'N° of barrels of gunpowder…not to exceed 1000' (Fig 91).

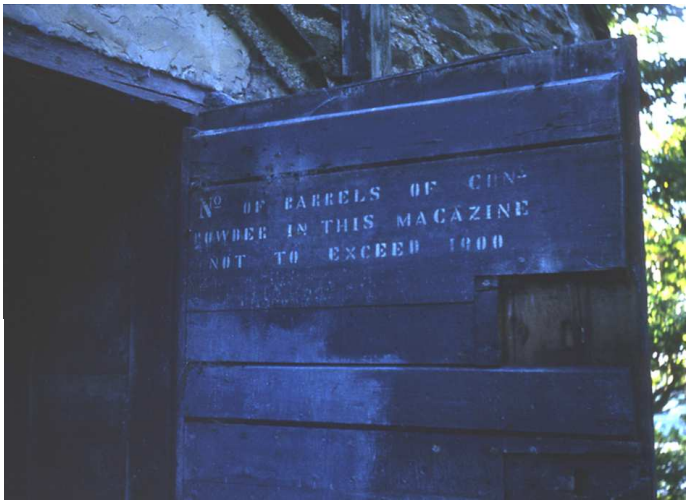


Fig 91. Noticeboard on the inside of the door to the '1798' Roudsea magazine in 1969. (Palmer Collection, copyright reserved)

A basic description and photograph of the 1836 magazine have already appeared in print (Bowden 2000, 33-5 and figure 2.16), but unpublished plans from the architectural archive deposit (NBR no. 103349) are reproduced here as Figs 92 and 93. These show the barn's suspended wooden floor - intended to combat ingress of damp - in some detail. Although this was an original feature integral to its use as a bark barn, it no doubt eminently suited the reuse of the building as a magazine as well. As built, the barn appears to have been provided with a loft some 2m above ground-floor level, but the joists are sawn off indicating that the loft was removed when the building was converted. Even so, the building at *c* 12.2m long by 7.4m wide internally was reportedly large enough to accommodate some 1500 barrels of gunpowder (Tyler 2002, 116). The entrance must have been situated in the north-eastern long wall fronting a track shown on OS maps (*eg* Ordnance Survey 1851, 1891 and 1913d). This wall is now almost entirely missing, but the surviving eastern return seems to terminate after *c* 0.8m at a door reveal (compare Bowden 2000, 35 figure 2.16). The pattern

of joist holes in the rear wall (Fig 92) also suggests that the loft floor probably ended some 3.1m short of the south-east gable. Taken together, these pieces of evidence point to the barn having been built with a set of double doors close to the east end of the north-east wall. An external porch was added in 1886 when Colonel Ford, HM Explosives Inspector, instructed

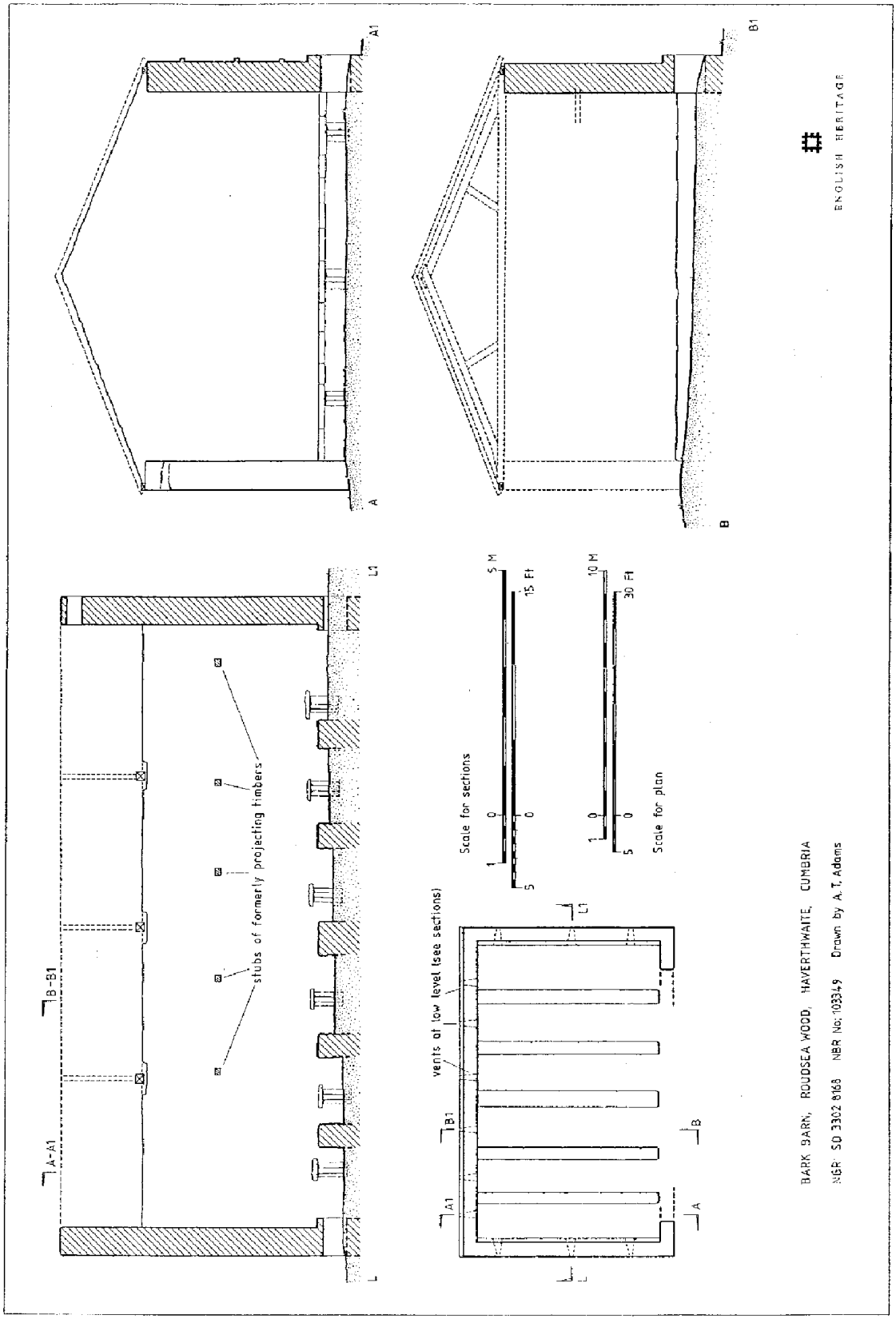


Fig 92.
EH archive plan and sections of the '1836' Roudsea magazine.
(NBR No. 103349, © English Heritage.NMR)

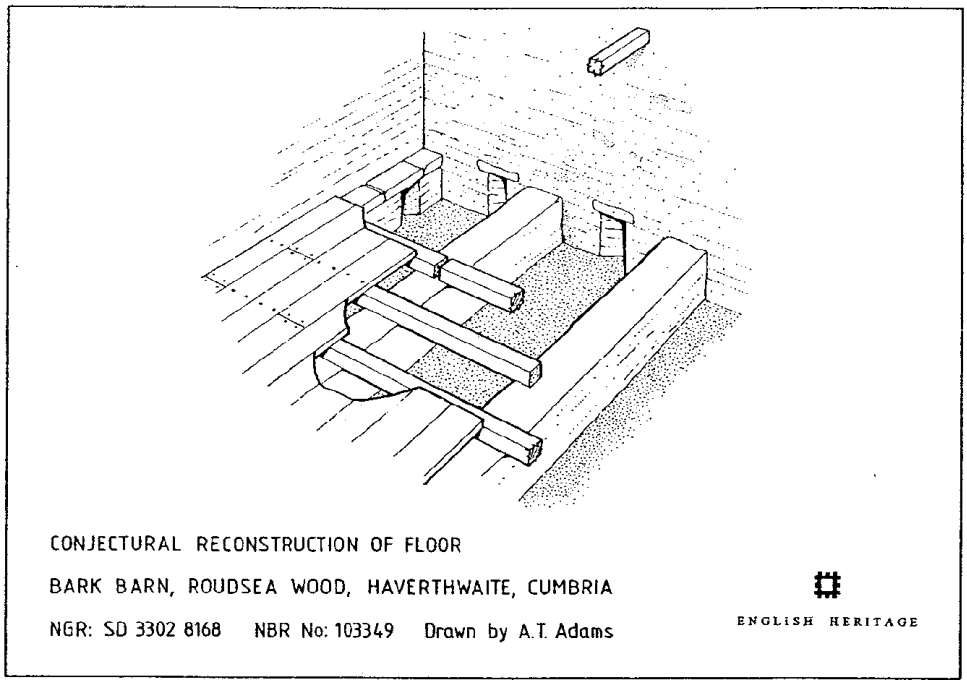


Fig 93. EH archive reconstruction drawing of the probable floor in the '1798' Roudsea magazine. (NBR No. 103349, ©English Heritage.NMR)

the company to fit the 'large magazine at Roudsea' with an outer door (HF LW/959/323). The OS map evidence also indicates that there was also some kind of wooden footwalk outside both magazines.

The 1798 magazine is in good repair, although now re-roofed and converted into a summerhouse with windows inserted into the north-west long wall, and the roof relaid and extended to the south-east to create a small verandah; a brick chimney stack has also been inserted into the building. It is unclear if the original door with its internal notice still survives. The converted bark barn, on the other hand, is a roofless ruin. As already stated, its north-east long wall is almost totally missing with the rubble seemingly cleared away; the other three walls stand to their full original height with only slight damage to the eaves and quoins.

Busky Magazine (building 1)

Once the Ulverston and Lancaster Railway was completed in 1857, the Lowwood company began to switch from sea to rail as the principal means of transporting goods, but found the two existing store magazines at Roudsea inconveniently situated for carts making deliveries of powder to Cark, the nearest station on the new rail line. It therefore decided to erect a new magazine closer to the factory, located in 'Busky field' just over 500m to the south-west, on a site which the 1863 sale plan shows was shielded from the main works by a rock outcrop '15 feet high'; the new Busky magazine was proposed in 1860 and operational by June 1861. However, a number of local residents objected to its siting, and in 1865 the Government appointed an inspector – Lieutenant-Colonel Boxer - to examine the issue of safety (section 4.2 above). Although Boxer seems to have found in the company's favour, it was probably at his recommendation that sets of outer doors were fitted to the magazine's porches in February 1865 (HF LW/1865/001, 002, 009 and 011). The OS first edition 25-inch map (Fig 7), surveyed in 1888, shows the building with two porches both fronting a tram line which emanated from the main factory and

terminated outside the north-west wall where it split into two branches, one of which no doubt served as a siding. The tram line was only laid in 1883-4, however (section 4.2 above); before then finished powder would have been taken to the magazine from the factory by horse and cart. The OS second edition map (Fig 8), revised in 1911, shows the building unaltered in shape apart from a small infill between the south-west side of the western porch and the corner of the magazine. After the works closed in 1935, the magazine was converted into a house called 'Busca'.

As first built, Busky Magazine was a gabled, single-storey building, 15.3m long by 9.2m wide, with a pair of slightly lower, gabled porches, 3.67m wide and 3.38m deep, projecting from its north-west wall. Its walls are built of roughly-coursed slate rubble, and originally lacked fenestration as was customary in store magazines. The main structure and porches have slate roofs, the main roof having three sets of purlins per side, the porch roofs just one set, all of them with shaped ends with a dominant cyma shape and a smaller cove. The conversion of Busky Magazine into a house involved inserting a series of windows in its outer walls and in those of its porches, blocking one of the porches, and subdividing the interior and inserting two chimneystacks (Fig 94); all these openings have modern slate-hung timber lintels.

Fig 94.
The former Busky magazine now converted into a private dwelling, 'Busca'.
(Ian Goodall, 2005)

Factory Magazine (building 60)

The evidence for building 60 on the Stang End side of the river having been a store magazine comes entirely from the 1926 factory plan (Fig 9), whose key describes it as 'Factory Magazine'. However, earlier maps show that the building existed by 1888 (Figs 7 and 8), and documentary evidence (HF LW/959/319) suggests that it was actually erected *c* 1886 in response to criticism from one of HM Explosives Inspectors, Colonel Majendie, that the company was using the heading-up house (building 49) for the illegal storage of boxes of blasting cartridges emanating from the cartridge-packing rooms (buildings 61 and 62, section 6.2.4 below) prior to their removal to the Busky magazine.

The OS first and second edition 25-inch maps indicate that the magazine was a slightly oblong building entered by a single central doorway in the southern wall protected by a small covered loading-bay or security porch; this doorway also fronted on to a tram line which connected the magazine directly with the cartridge-packing rooms. The 1926 factory plan shows a blast wall (here called BW13) shielding the east end of the magazine, but this is omitted from the two OS map depictions suggesting it may only have been added in the second decade of the 20th century. The factory plan does not indicate the magazine as stone-built, but this would have been a legal requirement and is confirmed by field evidence.

As a danger building, the magazine would have been cleansed by fire in 1935 when the factory closed. Its walls have since mostly collapsed although the inner face of the rear (northern) wall and northern return of the east wall survive up to *c* 1.3m high where the building has been terraced into the hillside; the general alignments of the remaining walls are traceable as low, spread, stony mounds. The eastern blast wall BW13 still stands to its full original height of *c* 3m with only slight damage. Evidence of small-scale quarrying immediately east of the blast wall (Fig 142) suggests that stone to build both it and the magazine was dug locally.

6.2.4 The Manufacture of Blasting Cartridges

The Explosives Act 1875 made the filling of blasting cartridges illegal except on licensed premises. Before the Act, cartridge preparation had been very much a home industry, often carried out by miners working by candlelight (Marshall and Davies-Shiel 1969, 84). After the Act, most blackpowder manufacturers obtained amending licences authorising new or converted buildings for the production of compressed cartridges. Following experimentation with loose-filled paper cartridges and problems with other manufacturers protecting their machinery designs by patents (*eg* HF LW/959/045, 046, 051, 100 and 122), Lowwood produced its first compressed cartridges in early 1882 (section 4.2 above). Until 1886, the company seems to have manufactured these cartridges at the high press house, but in 1886, it converted preparing house no. 1 to a dedicated cartridge-press house, and demolished the adjacent sieve house to make way for an hydraulic accumulator to power the press. Initially, the accumulator was raised by pumps driven from the old preparing-house waterwheel, but it was soon apparent that there was insufficient power in the wheel to operate the pumps adequately, and a new set of pumps was installed driven by the sawmill waterwheel; these were housed in a shed attached to the sawmill.

It was normal practice for gunpowder works to employ women to wrap the cartridges and pack them in boxes. At Lowwood, women performed this task in two new buildings which the company put up on the Stang End side of the river, where a dedicated changing-house or dressing-room was also provided. However, the cartridge-packing rooms and women's dressing-room were only erected between 1884 and 1886. Until the new buildings were ready, it is possible that packing was carried out by men employed at the 'final' packing house.

The 1926 factory plan (Fig 9) identifies the cartridge-press house as building 22, and the cartridge-press pump house and hydraulic accumulator adjacent to it as building 21; the replacement pump house at the sawmill is labelled as building 45a. The cartridge-press house had been renumbered building 31/32 by 1933/4 (reflecting the fact that by then it contained two presses), and the two pump houses as buildings 30 and 49 respectively (MMB, 30 and 32), but it is by their original numbers that all three buildings will be referred to in this report. The cartridge-packing rooms are listed as buildings 61 and 62 on the 1926 factory plan; their later numbers are unknown. The women's dressing-room is described in section 6.2.6 below.

Cartridge-Press House and Cartridge-Press Pump Houses (buildings 22, 21 and 45a)
Although the key to the 1926 factory plan (Fig 9) lists building 22 as 'Cartridge Press House', it also shows building 57 (high press house, this section above) authorised as 'Press House or Cartridge House'. The best explanation for this apparent duality of function seems to be that in the early 1880s Lowwood carried out experimentation into compressed-cartridge manufacture and initially produced cartridges at the high press house (*eg* HF LW/959/122), not opening a dedicated cartridge-press house until several years later. Thus the authorisation of the high press house as a cartridge house in 1926 is more likely to be an historical hangover than a reflection of the then current working practice. The view that cartridge manufacture was initially undertaken at the high press house is supported by documentary references which indicate that work to convert/rebuild the existing building 22 (previously preparing house no. 1, section 6.2.3 above) into a cartridge-press house, and replace the nearby sieve house (section 6.2.6 below) with a pump house to power the accumulator, only started in or shortly after April 1886. The company received notification at the start of April (presumably from the Explosives Inspectorate in response to an application for an amending licence) that in order to proceed with the conversion they would have to erect a blast bank shielding building 22 from building 41 (the low press house) to the north-east. A few days later senior managers began searching for a water supply sufficient and reliable enough to power the accumulator which was presumably to be located in building 21. By June it had been decided to use water taken from the stream issuing out of Bigland Tarn, conveyed to the works in a 3-inch (76.2mm) diameter iron pipe passing under Bigland Road (section 4.2 above, and HF LW/959/loose copy sheet addressed to the Cartmel Highway Board, dated 19 June 1886); the advantage of using water from the tarn was presumably because gravity meant it was already under partial pressure when it arrived at the pump house, thus reducing the amount of work the pumps were required to do to increase the pressure sufficiently to raise the accumulator. All construction work must have been finished very soon afterwards, for the new cartridge-press house was apparently being trialled in September (HF LW/959/323).

The company chose to position the blast bank it was required to erect by the Inspectorate adjacent to building 41 rather than next to the cartridge-press house (HF LW/959/313); this bank (BB1) has already been described elsewhere (low press house, section 6.2.3 above). However, by 1911 (Fig 8) an additional traverse (BB5) had been placed immediately south-east of the cartridge house in order to shield it from structures further east such as the charge house and incorporating mills. The 1926 factory plan (Fig 9) seems to indicate that the road from the charge house passed through the southern end of BB5 in a tunnel, but the suggestion is unsupported by other evidence (see below).

The layout of tram lines recorded on the OS first edition 25-inch map (Fig 7), surveyed in 1888, suggests that, initially, cartridge powder was stored in expense magazine no. 1, and brought from there direct to the press house as needed. Indeed, as soon as the press house opened in September 1886 the company was reprimanded by Colonel Ford of HM Explosives Inspectorate for breaking through without authority the existing blast wall outside the magazine in order to lay the tram line; the company was instructed to erect an additional mound to shield the low press house, or to reduce the amount of powder stored at the

magazine (HF LW/959/323). The evidence of the OS first edition map suggests that they chose the latter option as the map shows no blast bank adjacent to the press house. By 1911, however, the OS second edition map shows that this direct tram line had been lifted, and replaced by short spurs linking both buildings with a second line running between the charge house in the south and heading-up house in the north. The alteration probably reflects a desire to make the transport system match the direction of powder-flows between process buildings better, for the MMB (page 32) notes that by 1933/4 barrels of unstoved, glazed powder destined for cartridge manufacture could arrive at the cartridge-press house either from the magazine, or directly from the packing house (which was where the powder was weighed out into barrels: 'final' packing house, section 6.2.3 above). Once pressed, the cartridges were despatched to the stove house for drying.

The MMB (pages 30-4) also records that the cartridge-press house contained two hydraulic presses in 1933/4, but it is likely that one was much older than the other for it could only turn out cartridges of 1¼-inch (31.75mm) diameter, 8 per pound by weight, and 171 at a time, whereas the other was capable of producing a range of cartridges of different weights and sizes. Both were driven by an hydraulic accumulator with an $8^{3}/_{8}$-inch (212.8mm) diameter ram and 6-foot (1.83m) stroke, loaded to apply a pressure of 20cwts psi. This accumulator was originally raised by 'two sets of six hydraulic throw pumps' situated in the adjacent building 21, 'each fitted with two $1^{5}/_{8}$-inch (41.275mm) diameter rams x 3¼-inch (82.55mm) stroke and four 1¼-inch (31.75mm) rams x 3¼-inch (82.55mm) stroke' powered by the old preparing-house waterwheel. By 1933/4, however, these were seemingly seldom used as it had been found that the waterwheel was insufficiently powerful to operate them properly. Instead, they had been superseded by 'a set of three throw pumps fitted with $1^{7}/_{8}$-inch (47.625mm) diameter rams x 4-inch (101.6mm) stroke running at 44 rpm' situated in a shed attached to the sawmill, powered by a belt from the sawmill waterwheel/turbine. The 1926 factory plan shows that this shed (building 45a) lay close to the southern end of the sawmill's north-west wall, while other map evidence (Fig 7) indicates that it existed by 1888. It is tempting to equate the date of the new pump house's construction with the company's acquisition of the second cartridge press, but EH has found no evidence to confirm this suggestion.

The caption to a photograph taken in 1929 (Fig 95) records that the cartridge-press house was reconstructed as part of ICI's general modernisation of the works in that year. The extent of the reconstruction is unknown, but the photograph shows that the building was of stone construction (as, according to the conventions used on the 1926 factory plan, was its predecessor) beneath what appears to be a slated roof. It was entered by a doorway in the south-east long wall, shielded from the weather by a small porch which extended out over the tram line. The doorway was flanked by a

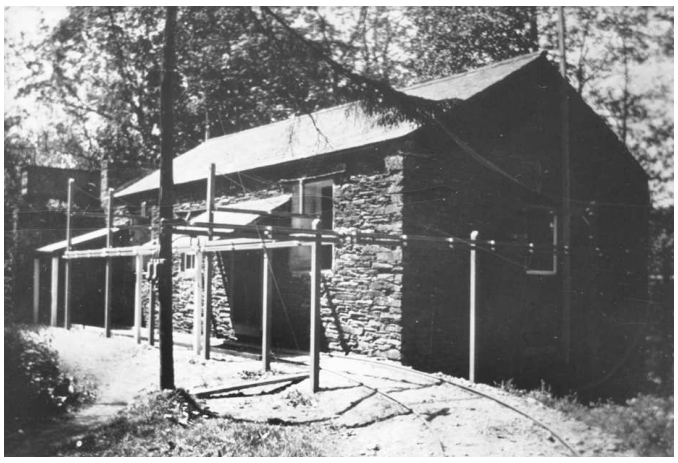


Fig 95. The reconstructed cartridge-press house, viewed from the east in 1929. (Patterson Collection, © English Heritage.NMR)

window to either side, and the building had at least one additional window in the south-west gable wall; the other gable end was most probably blind as it faced the wheel-pit. A framework of poles and wires around the front and sides of the building seems to be a system of earthing catenaries intended as protection against lightning strikes (information from Roger Thomas). Certain of the poles also seem to have doubled up as supports for electricity cables, but these were probably for lighting only. A switch discernible on a tree trunk in the left foreground indicates that the supply was controlled externally in order to remove the risk of electrical sparking within the building itself; the lights may also have been sited externally opposite the windows so that they lit the building from the outside.

The photograph suggests that the roof of the reconstructed cartridge-press house extended out over the wheel-pit adjacent to the south-west end wall, beyond which is another porch which must have protected the entrance into the pump house. The beam of the hydraulic accumulator can just be made out at the edge of the photograph, beyond the pump house.

By 1933/4, Lowwood produced only N/P powder (that is, gunpowder made using potassium nitrate saltpetre - see chapter 5 above); all its own cartridges, therefore, contained N/P powder. However, the works also undertook the pressing of a particular size of N/S (sodium nitrate) cartridge as it was the only factory in ICI's North of England gunpowder group to possess 1¾-inch (44.45mm) cartridge moulds; the N/S powder was imported to the works from its sister factory at New Sedgwick 16.5km away as the crow flies (MMB, 42).

No trace of the cartridge-press house or the adjacent pump house/hydraulic accumulator was found by EH during investigation, but the area is now covered in thick scrub vegetation; in addition, the site of the hydraulic accumulator may lie partly buried beneath the nearby modern hydro-electricity station. Blast bank BB5 adjoining the press house survives in reasonable condition between *c* 1.2 and 1.9m high depending on the slope of the ground, but there is no visible evidence for a tunnel through its southern end. A cast-iron pipe which is visible (Fig 142) only where it crosses the headrace close to the joiner's shop (building 20), may represent the piped water supply from Bigland Tarn for the hydraulic-accumulator pumps. The visible length of pipe is *c* 127mm in diameter, against the 3 inches (76.2mm) which documents state was the size of the piping used (this section above), but it is unclear if the latter measurement represents the internal or external diameter.

There is no surviving trace of the pump house at the sawmill, although its approximate location is shown on Fig 100 which attempts to reconstruct the layout of the mill and its associated buildings. EH did identify a small concrete machine base with four sawn-off iron holding-down bolts forming the vertices of a rectangle, however, close to the sawmill's western corner. As this seems to be within the limits of the pump house as indicated by OS map evidence, it probably represents the base for one or more of the pumps.

Cartridge-Packing Rooms (buildings 61 and 62)

The key to the 1926 factory plan (Fig 9) names two very similar-sized buildings adjacent to a short tramway spur on the Stang End side of the river as 'Cartridge Packing Room[s]'. They must have been built between 1884 and 1886: although Lowwood commenced cartridge manufacture in

1882 (this section above), buildings on this side of the river are unlikely to pre-date the construction of the tram line to Haverthwaite Station in 1884 (section 4.2 above), while 'cartridge packing houses' are mentioned in a letter reporting an inspection of the works made in May 1886 by Colonel Majendie (HF LW/959/319). Cartridge packing must therefore have been carried out elsewhere in the factory for at least a couple of years before these two buildings were ready – most probably at the 'final' packing house (section 6.2.3 above). The factory plan depicts a blast bank (here called BB7) between the two packing-rooms, but this feature is missing from both the OS first and second edition 25-inch maps (Figs 7 and 8), surveyed in 1888 and 1911, and may therefore only have been erected in the second decade of the 20th century. As the factory plan does not show either of the rooms as stone danger buildings, both are likely to have had timber walls and either metal or felt roofs. It is also possible that both rooms were heated by steam or hot-water pipes leading from the boiler house attached to the nearby women's dressing-room (section 6.2.6 below), although EH has found no documentary or physical evidence to substantiate such a suggestion. It seems that one of the rooms was disused by 1933/4, for the MMB (page 42) speaks of the 'cartridge packing building' in the singular, and states that only three women were then employed.

Cartridges were wrapped end on, two to a paper, and placed in boxes lined with waxed liners. Once each box had been packed with 50lb (22.7kg) of cartridges and had had its lid nailed on and a stencil applied, it was taken to the nearby factory magazine (building 60, section 6.2.3 above) to await despatch to customers.

No physical trace of either building was found by EH during the current investigation. The intervening blast bank (BB7) does survive, however, as an overgrown but otherwise well preserved, rectangular, earthen mound, *c* 1.2m high with a flat top and steeply-sloping sides capped by large cobbles (Fig 96).

Fig 96. Blast bank BB7 between the cartridge-packing rooms, viewed from the east. (NMR DP006418)

6.2.5 Testing the Powder

In the 19th century the Government required gunpowder supplied to the military by civil contractors to be tested or proved before it was accepted into government magazines. Two tests were used: one involved firing a special steel musket-ball through fifteen wooden boards, ½-inch (12.7mm) thick and placed ¾-inch (19mm) apart; the other firing a 64lb (29kg) cannon ball from a mortar angled at 45° using a 2oz (0.06kg) charge of powder, with the expectation that the ball be propelled at least 247 feet (75.29m) (Cocroft 2000, 46-8; Tyler 2002, 117). When Lowwood began competing for military contracts around 1862, it had its own proofing range complete with proof houses. It is uncertain if these facilities existed much before this time (there is slight evidence for the presence of an earlier proofing range at Lowwood, but if so this was located elsewhere and was disused by 1846). Production of military-grade powders, however, was an ill-fated venture rapidly abandoned

(section 4.2 above), and the range and proof houses, too, appear to have been quickly disused. It is unclear how Lowwood tested its powders *post* 1863, but other methods of proving the quality of powder in the 19th century included 'flashing' it on hot copper sheets; by the 20th century the composition of powder could be analysed chemically in the laboratory. A laboratory is recorded at Lowwood in 1926, but it is unclear what it analysed.

The contemporary building numbers for the two proof houses are not recorded. Both houses, however, survived until closure, adapted to other uses (harness room and loose box, section 6.2.9 below). They are depicted on the 1926 factory plan as buildings 39 and 40, which are therefore the numbers used to refer to them both in the description below and also on the relevant phase diagrams (Figs 135-6).

Proofing Ranges and Proof Houses (buildings 39 and 40)

The earliest documentary evidence for the existence of a proofing range at Lowwood is the 1863 sale plan (Fig 6), which shows a 'Proof Ground' located at the centre of the works. Two buildings labelled 'Gun[s]' are depicted opposite the northernmost incorporating mills, each with a range marked out as extending for about a furlong (approximately 200m) to the north-east. It is unlikely that the buildings actually housed guns or mortars: the schedule in the accompanying indenture refers to the ranges as 'proof houses and mortar' (section 4.2 above), and the two buildings may have been akin to the proof house at the Government-run Marsh Works at Faversham which stood at the head of the range opposite the mortar; the Marsh proof house was brick-built beneath a pyramidal roof surmounted by a lantern for ventilation (Cocroft 2000, 47-8). It is unclear for how long the two Lowwood proof houses and ranges were in use. The OS first and second edition 25-inch maps (Figs 7 and 8), surveyed in 1888 and 1911, both show small unnamed structures in roughly the same positions as the proof houses portrayed in 1863, but the key to the 1926 factory plan (Fig 9) describes them as 'Harness Room' and 'Loose Box' (section 6.2.9 below); in addition, none of the later maps portrays or names a range. It is possible, therefore, that live firings had been abandoned by this time and replaced by other less spectacular forms of proofing conducted in the laboratory, although George Shackley's recollections of building 16 having served as a cannon-ball store *c* 1928 (this section below) suggests the contrary.

At least two United Kingdom gunpowder factories – New Sedgwick in Cumbria (Dunn *et al* 2003, 90-2), and Oare in Kent (Cocroft 2000, 48 and 110) – are known to have had proofing ranges delimited by trees; in the former case, the range was of cruciform plan and mostly marked by sycamores, at the latter it was a straightforward avenue flanked by Wellingtonias. The advantage of both species is that they are reasonably fast-growing. There is no evidence that the Lowwood range documented in 1863 was ever similarly tree-lined, but it is perhaps worthwhile drawing attention to the depiction in 1888 on the OS first edition 25-inch map of a row of three trees aligned roughly north-west to south-east in amongst the incorporating mills at the southern end of the works. Whilst these could represent the line of a grubbed-out former field boundary, they do not correspond well with detail on the 1796-9 Bigland estate map (Fig 3), and are therefore more likely to be deliberate plantings by the Lowwood company. Two of the depicted trees can be matched with mature ash trees which still survive, but in addition three other ashes of similar age exist close by either as extant standards or, in one case, as a stump (Fig 142). The three mapped trees and the stump are

all pretty much in line; the other two standards are offset to the north-east, one by 6-7m from that line, the other by 27-28m. Intriguingly, perpendiculars drawn to the line from these outliers are themselves only 6.8m apart. This raises the possibility that the planting is the remnant of an early tree-lined range of T-shape if not cruciform plan. In comparison, the trees flanking the range at New Sedgwick are all positioned approximately 6m apart.

However, a couple of cautionary notes need to be sounded. First, if these trees are evidence of an earlier range, that range must pre-date the particular mills which now surround it, which documentary evidence suggests were built between 1828 and 1846 (sections 4.2 and 6.2.3 above). In contrast both the New Sedgwick and Oare ranges date to the second half of the 19th century or early 20th century. Secondly, it is not impossible that the trees were deliberate plantings by the Lowwood company, but intended purely as extra blast protection shielding the incorporating mills, for it was a recognised fact that tree crowns helped to curtail the distance over which burning débris spread when, inevitably, mills exploded (see blast banks and walls, section 6.2.10 below).

Canon-Ball Store (building 16)
Although authorised on the 1926 factory plan (Fig 9) as the fire-engine house, George Shackley seems to have remembered this building as in use around 1928 for the storage of timber and cannon-balls (information from Mike Davies-Shiel). The matter is incapable of further resolution on the evidence available.

Laboratory (building 11a)
The only evidence for a laboratory at Lowwood is the 1926 factory plan (Fig 9) which identifies the very end of the more eastern of the two southern wings of the saltpetre refinery as then authorised for such use (building 11a). However, it is improbable that this was a proofing laboratory; it is more likely to have been connected instead with testing the quality of grough (crude) saltpetre arriving at the works (section 6.2.2 above).

6.2.6 Ancillary buildings

Watch House, Changing-Houses and Search Houses
It was standard gunpowder-industry practice for the keepers of the incorporating mills (those whose jobs it was to load green charges and unload ripe charges) to supervise the incorporation process itself – which could take anything from one to several hours - from the safety of a watch house. This was in order to minimise the risk of death and injury if a mill exploded, as seems frequently to have happened (Appendix 1 below).

As a further safety precaution, many gunpowder factories also searched their entire workforce for contraband (that is, items such as pipes and matches and anything metallic which presented a risk of fire or of striking a spark, and therefore might cause explosions) when they reported for shift. In addition, those people employed in danger buildings were also required to put on special clothes and shoes: the clothing (made from inflammable materials) was designed to provide a degree of protection against burns, but also lacked pockets as an added safeguard against the secretion of contraband about the person; the shoes were either entirely of leather or only contained non-ferrous nails so as to reduce the risk of

striking sparks. Searching and the donning of such apparel were made statutory requirements under the Explosives Act 1875, but had been normal practice at many works for a long time before this (Public Statutes General 1875, 151; Cocroft 2000, 60 and 99): Lowwood, for example, introduced leather clothing for its workers as early as 1805 (Palmer 1998, 48).

Lowwood appears to have used the same watch house throughout the 136 years of its existence. Before 1928, male workers were searched and also changed into their special clothes at the watch house, although after that date new washing and changing facilities were installed in the north-east wing of the disused saltpetre refinery (Clocktower complex). From the 1880s when women began to be employed to pack blasting cartridges, a separate changing-house (styled a dressing-room) was provided especially for them; again, searching of women was carried out in the dressing-room (HF LW/959/368). The dressing-room was constructed *c* 1884, and stood on the Stang End side of the river.

The 1926 factory plan identifies the watch house and women's dressing-room as buildings 18 and 63a, which are therefore the numbers used for them below. The same plan also names a boiler house (building 63) attached to the dressing-room; this presumably heated the latter (and possibly the cartridge-packing rooms, too) and is also described below. For the purposes of the present report the new washing and changing facilities at the Clocktower complex appear on the relevant phase diagram (Fig 141) as building 11b.

Watch House (building 18)

The earliest documented mention of a watch house at Lowwood occurs on the 1863 sale plan (Fig 6), which places it at the southern edge of the oval of incorporating mills. However, the likelihood is that the building had existed and performed this function since 1799; it probably continued to do so until 1935 for George Shackley remembered that it was still the watch/changing/search house in 1928 (information from Mike Davies-Shiel). In 1863 it was said to contain beds for the comfort of the mill keepers (HF LW/1863/161).

The sale plan depicts the building as a simple rectangular construction, whereas subsequent maps and plans (Figs 7-9) show it as L-shaped with a small extension at the south-west corner. This extension was presumably added in late 1881 or early 1882, for a note on the 1926 factory plan states that a 'Stone erection' to building 18 was authorised in October 1881; the need for it is undocumented. According to George Shackley, building 18 was a two-storey affair with the northern half of the ground floor in use as the mill men's room (*ie* watch house) and the southern half as the search house and waiting-room (where the men gathered prior to the start of their shift); upstairs was used as the changing-house.

As a non-danger building, the watch house was presumably simply abandoned when the works closed in 1935. However, RAF aerial-reconnaissance photography curated at the NMRC indicates it had already disappeared by August 1945 (*eg* 106G/UK653, frame 3112). The site was subsequently partly buried in 1952/3 by the massive embankment raised to retain the re-routed headrace to the hydro-electricity station. The only trace visible on the ground today, in an area heavily overgrown, is a short length of scarp which would appear to be in the correct plan position for the north-west gable wall (Fig 142).

Men's Washing and Changing House (building 11b)

According to George Shackley, in 1928 the ground floor at the northern end of the disused saltpetre refinery (distinguished as building 11b on Fig 141) was given over to a washing and changing area for the male workforce as part of ICI's programme of modernisation of the works. An upright water boiler was reportedly installed against one of the old fire grates in the 'boilerman's passage', with wash tubs laid out on planks against the wall opposite, and showers installed in the former warehouse behind (information from Mike Davies-Shiel).

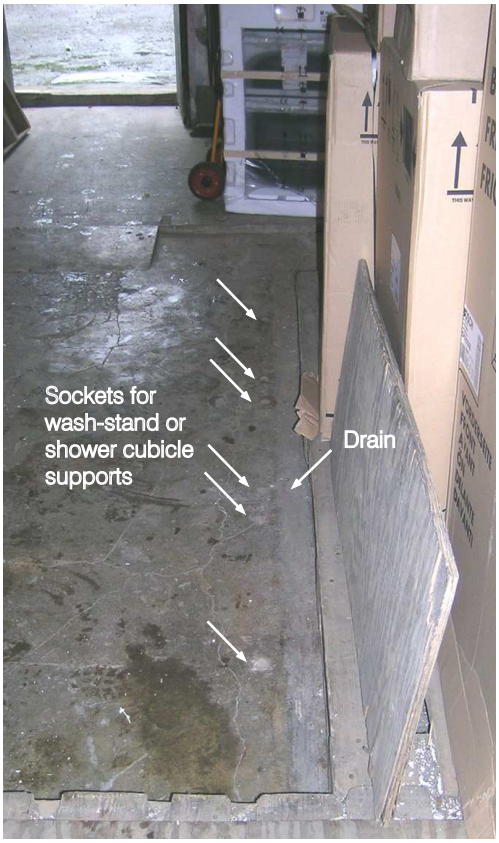


Fig 97. The shallow drain and sockets for wash-stand or shower cubicle supports (arrowed) in building 11b. (Tony Berry, June 2005)

This eye-witness account can be substantiated in its essentials from surviving field evidence, for a short stretch of shallow open drain (Fig 97) is preserved in the concrete floor of the northernmost of the two ground-floor rooms forming the north-east wing of the refinery (Fig 27); the sockets for three wash-stand supports or shower cubicles are also visible arranged along its length. Unfortunately, both rooms are now used as a stockroom, and pallets and goods obscure the remaining floor area and much of the walls. The boiler was probably located at the northern end of the boilerman's passage (Fig 27), on the small area of floor which has been concreted over; impressions of timber studwork at the edges of the concrete and on the walls adjacent show that this area was at one time screened off from the rest of the passage.

Women's Dressing-Room and associated boiler house (buildings 63a and 63)

The 1926 factory plan (Fig 9) shows the women's dressing-room located on the Stang End side of the river. Although the company started manufacturing cartridges early in 1882, it is highly improbable that any gunpowder buildings existed on this side of the river before the construction of the tram line to Haverthwaite Station in 1883/4 (section 4.2 above). If women were employed to pack cartridges before this date – for example, at the heading-up house ('final' packing house, section 6.2.3 above) - the location of the accompanying female changing-house is unknown. The factory plan records a boiler house attached to the south-west end of the dressing-room, presumably to heat the building. There is no evidence that the men's watch/changing-house was similarly heated at this time (although both watch houses which existed at the nearby Blackbeck factory had fireplaces (Dunn *et al* 2005, 90-3); it may be that the social conventions of the day considered women as more in need of such sensibilities.

The factory plan records buildings 63 and 63a as standing midway between, and directly in line with, the river and the more southerly of the two cartridge-packing rooms. Neither the OS first nor second edition 25-inch maps (Figs 7 and 8), surveyed in 1888 and 1911, has a

building depicted at this location, although each portrays a structure some 16m to the south-west not represented on the 1926 factory plan. As the EH investigation found no field evidence for a building at the former location, but did locate the structure indicated on the OS maps, it seems likely that buildings 63 and 63a are misplotted on the factory plan and actually lie at the location portrayed by the OS.

The extant building, which is both ruinous and heavily overgrown (Fig 98), is built of stone rubble beneath a double-pitched corrugated iron roof, the collapsed remains of which now obscure the interior. Three walls (namely the north-east gable wall and both long sides) survive, 0.6m thick and where best preserved up to 2.2m high. The building appears to have been lit by a small window in each surviving wall, although the south-eastern long wall is badly decayed and the evidence here less certain. However, at 3.76m long by 2.94m wide internally, the surviving structure is shorter than that depicted on the maps, possibly because the boiler house at the south-western end has been demolished; it appears to have been separated from the stone-walled dressing-room by a low concrete partition, 0.5m high by 0.35m thick, which presumably supported some form of timber framework above. This partition terminates short of the south-eastern long wall, suggesting the position of a doorway between the two halves of the building. As there is no evidence of a doorway in any of the surviving stone walls, the dressing-room must have been entered through the boiler house. It is likely that the door into the boiler house lay in the north-west wall, as the building was originally approached by a path which descended the hillside from the direction of the more northerly of the two packing-rooms: the course of this path can still be traced in places as a narrow earthwork terrace running diagonally across the natural slope (Fig 142).

Fig 98.
The remains of the women's dressing-room, viewed from the south. The concrete wall in the foreground presumably marks the division between it and the boiler house which has now disappeared. (NMR DP006419)

Buildings associated with Carpentry and Coopering

Gunpowder works consumed large quantities of timber. After constructing, fitting out and then maintaining the many buildings, the most obvious need was for planks and staves to make the barrels (and later cartridge boxes) in which powder was transported and sold. Much of the infrastructure and machinery (for example, waterwheels, axles, pit-wheels, bevel and pinion wheels, cog teeth, drive shafts, sieve frames and such like), as well as the wagons and dreys, was also constructed in timber and needed specialist on-site repair and maintenance. At a basic level, therefore, a gunpowder factory could be expected to contain a sawmill plus one or more cooperages and carpenter's shops; many, including Lowwood, also possessed other, more specialised, facilities.

The Lowwood sawmill appears to have occupied the same site throughout the 136 years that factory was open. The exact date Lowwood began manufacturing barrels is uncertain

(see below), but by the mid-19th century the sawmill was doubling up as a heading shop for the production of barrel lids. The sawmill was powered by its own waterwheel, but prior to 1861 this wheel was evidently not working at full capacity for when the low press house was constructed the associated hydraulic pumps drew their power from the sawmill; later (possibly by 1888) the wheel at the sawmill also powered pumps for the new cartridge-press house. Both sets of pumps were housed in wooden sheds attached to the sawmill. In 1910 the waterwheel was replaced by a water turbine, and shortly afterwards an oil engine was installed (again in its own attached shed) to augment the turbine's output in periods of low water or high demand. By 1928, as well as powering the pumps already mentioned, the turbine also drove: a boring machine, turning machine and stave saw within the building; a stave-shaping saw, crosscut saw, and saw or lathe for dressing mill-stones in separate attached sheds; and a travelling saw in a free-standing shed.

The 1926 factory plan (Fig 9) identifies the sawmill as building 45, the attached oil-engine shed as building 64, and the free-standing shed for the travelling saw as building 65, and these factory numbers have all been retained in the discussion below and on Figs 132-41. The oil-engine shed (building 64) seems to have replaced an earlier structure - of unknown function - depicted in 1911 (Fig 8), here called building 45f. The stave-shaping-saw, crosscut-saw, and millstone-saw sheds are not differentiated on the factory plan, but are here numbered buildings 45c, 45d and 45e. The press and cartridge-press pump houses (buildings 45b and 45a) have already been described in detail in connection with the low press and cartridge-press houses (sections 6.2.3 and 6.2.4 above), and will only be referred to briefly below.

When Lowwood opened in 1799, it initially sold powder in barrels reportedly purchased from a firm in Kendal (Tyler 2002, 98). One or more cooperages must have been established on the site in the early 19th century, however, since by 1846 three of the four cooperages named on the 1863 sale plan had already been erected (compare Figs 4 and 6). The latter plan shows four cooperages, all located on the boundary between the factory and Low Wood hamlet. Coopering seems to have been discontinued at the works after 1928, although one building may have survived in use for longer as a box-making shop. On the 1926 factory plan, the cooperages are listed as buildings 2 – 5: these numbers are therefore the numbers used to identify them on the phase diagrams (Figs 132-41) at the end of the present report, but for convenience the buildings will be referred to below as cooperages nos. 1 – 4. As it happens, cooperage no. 4 seems to have been the last to be built *c* 1860, but the designations have simply been allocated in a clockwise manner from north to south and do not necessarily reflect the original order of construction.

Cooperages were where, amongst other things, barrels were assembled, but the component parts for the barrels were manufactured in a range of other buildings across the factory. As already noted, at Lowwood barrel lids were produced and staves cut to length at the sawmill/heading shop, but there was also a separate stave-drying shed and attached boiler house, and a stave-hollowing machine at the works. The 1926 factory plan identifies the former as buildings 67 and 66. The stave-hollowing machine was reportedly housed in the northern end of a two-celled structure tacked on to the outside of building 17 (the small charcoal barn/cask store opposite the saltpetre refinery); it seems not to be depicted on the factory

plan, but is here numbered building 17b. Lowwood also possessed at least one joiner's shop by 1863, plus various wood stores; by 1926 it also had a sawpit. The factory plan identifies the joiner's/carpenter's sheds as buildings 19 and 20, the wood stores as buildings 9 and 10, and the sawpit as building 6; the same numbers are used for all these structures below.

Sawmill / Heading Shop, attached saw-sheds and associated oil-engine house (buildings 45, 45c, 45d, 45e, 45f and 64)

Although Lowwood is likely to have had its own sawmill as early as 1799, there is no confirmation of its existence before 1863 when the schedule in the sale indenture lists a 'sawing house, turning shop and machinery' (section 4.2 above), and no evidence for its siting until just before closure when the 1926 factory plan (Fig 9) shows the sawmill located towards the southern end of the works astride a leat coming off the main headrace opposite the lower stove. Earlier maps show that both building and leat existed by 1846 (Fig 4), however, suggesting that the sawmill occupied the same site throughout the lifetime of the works. Strangely, neither sawmill nor leat is depicted by the 1863 sale plan (Fig 6), but this must be a simple omission probably reflecting the speed with which that document was drawn up (section 4.2 above). The fact that in 1846 the sawmill is shown with a different footprint to later maps indicates that it was rebuilt or extended sometime between then and 1888 (the survey date of the OS first edition 25-inch map).

The sawmill doubled up as a 'heading shop' from early on, for in 1867 it was reported that the 'Sawing House and Heading Machine were brought to a complete standstill…the large Drum and a portion of the Shafting having given way' (HF LW/958/971). The reference is not to a heading-up or packing house (which stood elsewhere (section 6.2.3 above)), but rather to a workshop where boards for barrel-heads were cut to shape and fitted. The sawmill still served this function in the 1920s (see below).

In 1864 it was reported that the sawmill waterwheel was also being used to power pumps at the nearby low press house (HF LW/1864/075), constructed in 1861 (section 6.2.3 above). This indicates that the waterwheel had considerable spare capacity, and probably accounts for plans mooted in 1864 and again in 1872 (HF LW/1864/029 and LW/1872/008) to relocate the sawmill elsewhere and reuse the site for extra process buildings. However, the proposals came to nothing on both occasions. (The 1872 proposal involved replacing the sawmill with four new incorporating mills, but was never implemented for reasons of cost (section 4.2 above)). Later (probably by 1888) the sawmill waterwheel was also powering pumps for the cartridge-press house (section 6.2.4 above). Early in 1910 the waterwheel was superseded by a Gilkes 29.8kW 'Trent' turbine, manufacturer's no. 2065 (section 4.2 above), but the practice of powering both the low press house and cartridge-press house pumps from the sawmill seems to have persisted until closure in 1935, for the key to the 1926 factory plan describes the mill as 'Saw Mill & Pump' and names a shed attached to the western corner as 'Cartridge Press House Pumps'.

Details about the machinery housed at the sawmill is provided by the recollections of George Shackley who worked at Lowwood in the 1920s and later described the building's form and internal layout in considerable detail to both Mike Davies-Shiel and Ron Mein. Apparently, the waterwheel (and subsequently the turbine which replaced it) powered two

internal overhead drive shafts running the length of the building, one against each long wall: that against the rear wall of the building drove pumps for the low press house, a turning machine, millstone-saw and travelling saw (the latter in its own divorced shed, building 65 - see below); that against the front wall powered pumps for the cartridge-press house, a boring machine, stave-shaping saw, stave-saw, and crosscut saw. The stave-shaping, crosscut and millstone saws were all housed in lean-to sheds attached to the front and north-east gable walls of the mill. The first of these was probably one of the wooden erections referred to in a note on the 1926 factory plan as authorised in October 1881; it certainly existed by 1888 because it is depicted on the OS first edition 25-inch map (Fig 7). Later map evidence shows that the crosscut-saw shed was added between 1888 and 1911 and the millstone-saw shed between 1911 and 1926 (compare Figs 7, 8 and 9). The 1926 factory plan also shows another shed (building 64) attached to the eastern corner of the sawmill, and identifies it as 'Oil Engine House'. According to Shackley, the oil engine was installed to augment the power output from the sawmill turbine. The shed must therefore post-date 1910; indeed it is later than 1911 for the OS second edition 25-inch map (Fig 8) shows that it replaced an earlier structure of unknown function (here numbered building 45f). Shackley also stated that the low press and cartridge-press pumps were accommodated in separate sheds against the south-west gable of the mill, but given the contrary evidence of the factory plan for the site of the cartridge-press pump house, it seems probable that in this particular detail at least Shackley's recollection of the layout of the mill is imperfect. Shackley's information has been combined with the documentary and field evidence to produce Fig 100.

The sawmill was presumably simply abandoned when the works closed in 1935. Post-war aerial photography shows that it was roofless by 1945 (*eg* NMRC 106G/UK 653 frame 3112), and although the walls were mostly still upstanding in 1968 when Mike Davies-Shiel visited the site and made a couple of small sketches (reproduced here as Fig 99), much of the superstructure has since either collapsed or been demolished; only the basic outline of the more southern half of the mill plus the wheel-pit and Gilkes turbine which is still *in situ* within the latter, can now be made out on the ground. Collapse/demolition of the building is no doubt largely attributable to water leaking from the headrace; this collects to the rear of the mill in a large and relatively modern drainage lagoon which has been dammed in order to channel water overflowing from it into the

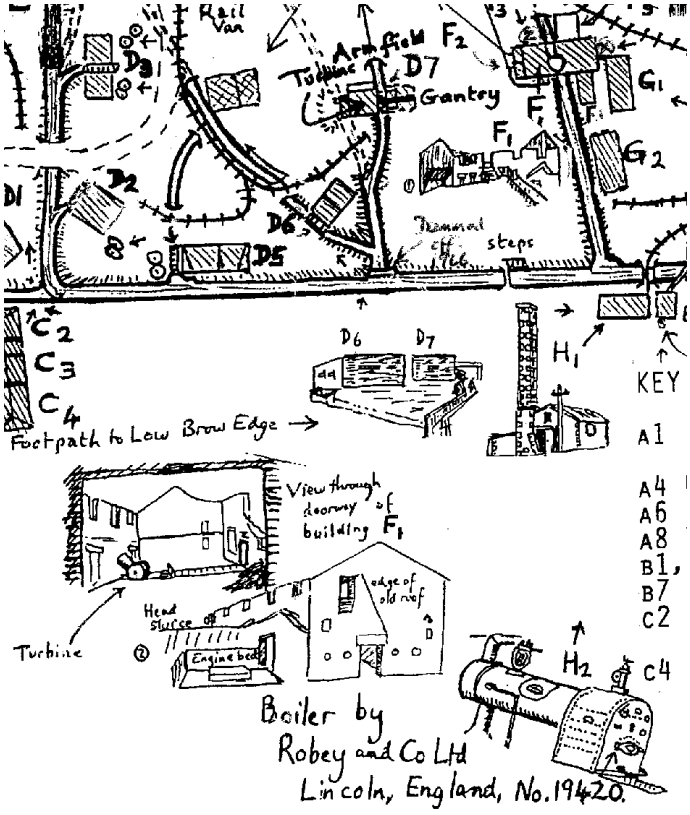


Fig 99. Extract from a sketch map of Lowwood produced by Mike Davies-Shiel in 1968, incorporatring internal and external views of the sawmill (labelled building F1) and attached outbuildings. (Davies-Shiel Collection, copyright reserved)

sawmill (entering through a probable doorway in the rear wall) to drain away into the wheel-pit and its culverted tailrace. Some of the leakage from the headrace also flows along the sawmill leat and into the concrete-lined turbine header-tank immediately behind the mill.

This tank is a replacement for the pentrough which would have fed water onto the sawmill's waterwheel prior to the installation of the turbine in 1910. It is surrounded by a concrete platform which obscures the north-western end of the tank and also projects for *c* 1m beyond the south-west side wall of the tank's supporting structure (Fig 101), where the original metal guard rail still survives. Water was fed onto the turbine through a circular-section feed-pipe let into the northern corner of the tank, which also passed

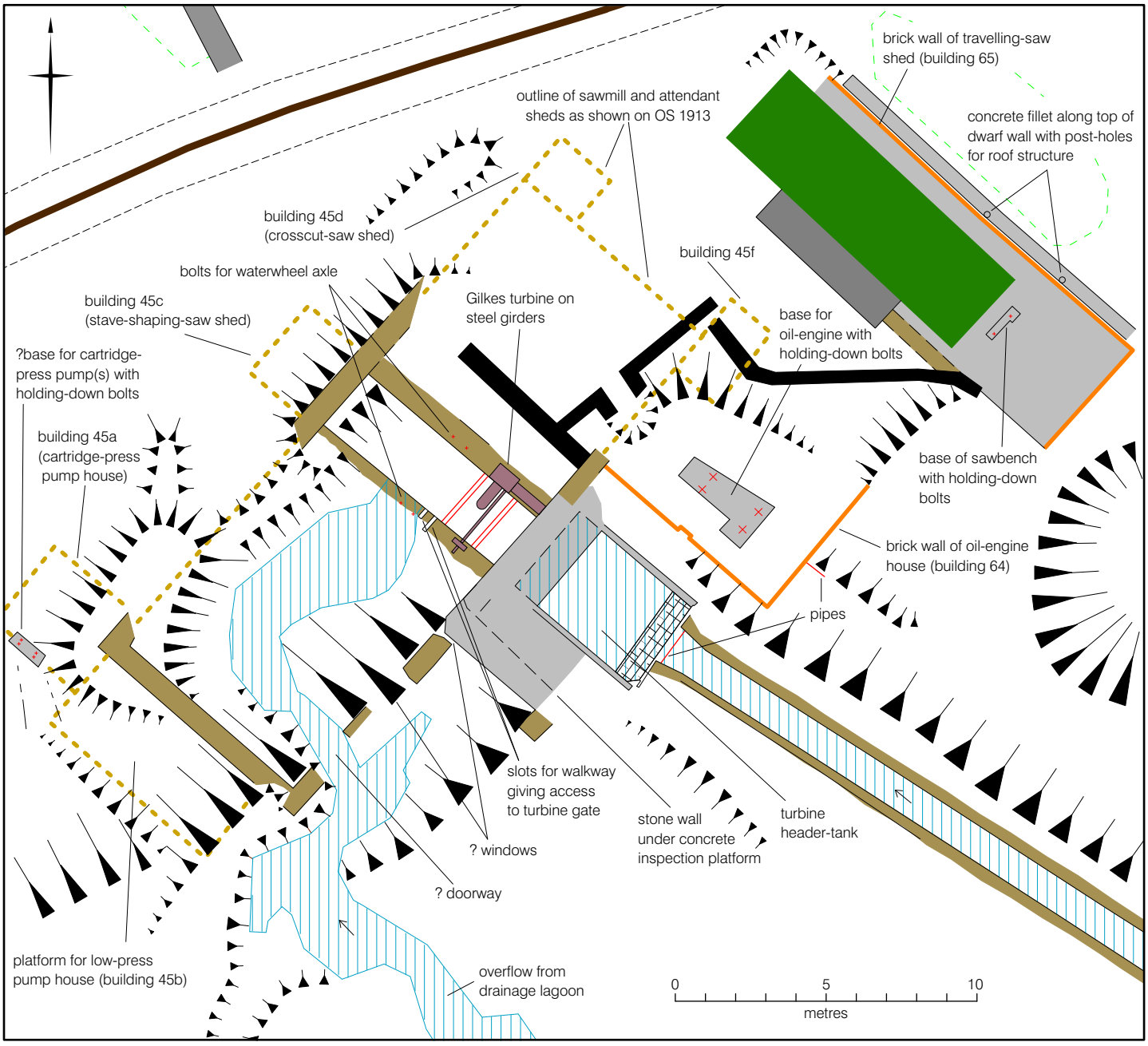


Fig 100. EH interpretative plan of the sawmill and associated buildings. (For key to conventions, see Fig 142)

Fig 101. The sawmill and turbine header-tank at the end of the sawmill leat, viewed from the west. (NMR DP003445)

Fig 102. Gilkes turbine no. 2065 at the sawmill. (NMR DP003446)

through the rear wall of the sawmill to the turbine located on the northern edge of the former wheel-pit (Fig 102). The turbine gate was controlled by a circular turning-handle situated above the discharge-pipe (of identical circular section to the feed-pipe), which emptied back into the wheel-pit; the handle was accessed from a metal walkway which now lies collapsed in the bottom of the pit, but whose original position is indicated by the slots cut to accommodate its metal supports which are preserved in the pit's southern edge. Two metal girders which still span the pit supported the discharge-pipe and shafting for a flywheel. The words 'GILKES' and 'No. 2065' are cast into the turbine housing. The entrance to the culverted tailrace - which must lie at the far end of the pit - is presently obscured by wall tumble, but the positions of the bolts for the former waterwheel axle-mounts are still visible on either side of the pit, set into what appear to be fragments of a broken bedstone from the incorporating mills.

The evidence of the Davies-Shiel sketches suggests that the sawmill was originally a two-storey building beneath a double-pitched roof, with the upper floor lit by four windows in the rear elevation and two more in the gable walls, but because of the perspective of the sketches it is impossible now to say whether there were further windows at this level in the building's front wall. At ground-floor level, the sketches indicate a slightly off-centre doorway in the north-east gable wall, another giving access to the oil-engine house at the north end of the rear wall, and possibly a third towards the southern end of this wall where there was also at least one window. The existence of at least one doorway and two windows at the southern end of the rear wall is confirmed by field evidence which indicates the presence of three splayed or square-sided openings here, one now mostly obscured beneath the overhanging concrete access platform surrounding the turbine header-tank (see below). According to George Shackley, the mill had two more doorways in its front wall either side of the wheel-pit, but if so both are now completely obscured by tumble. Davies-Shiel's sketches also indicate an old roof line against the north-east gable wall, probably part of the millstone-saw shed. Square recesses shown on either side of the doorway in the gable wall are

presumably boxes for the drive shafts to the crosscut-saw, millstone-saw and travelling-saw sheds. However, all trace even of the plan of this end of the sawmill has been removed or obscured by modern landscaping.

Very little survives at the position which the 1926 factory plan indicates for building 64, either. The main evidence is a small platform terraced into the rising ground behind the sawmill, with the platform sides retained by an L-shaped brick wall *c* 1.2m high (Fig 100). This walling presumably correspond to the south-west and south-east walls of the oil-engine house, although the size of the structure evidenced by the field remains is considerably larger than that suggested by the plan, suggesting it was rebuilt after 1926. It is unclear if the brick wall originally returned along the north-east side of the platform too, for a low dry-stone wall (part of the modern landscaping for the nearby caravan stance which now occupies the site of the travelling-saw shed (this section below)) runs at the foot of much of this side of the platform. The platform floor so defined is largely grassed over, but the outline of a concrete machine-base can still be discerned slightly off-centre within it, from which protrude the sawn-off ends of four metal holding-down bolts arranged as the vertices of an irregular quadrilateral 1.9m long by 0.55-0.78m wide: these presumably represent the fixing bolts for the engine itself. An iron pipe of 50mm diameter which projects over the top of the rear wall and turns downwards in line with the centre line of the machine base is presumably a water pipe; a pipe of similar diameter which crosses the sawmill leat at the latter's junction with the turbine header-tank, and two more which are exposed in the former overflow channel from the lagoon, are presumably in some way all associated with it. A roof-line scar visible in the Davies-Shiel sketches (Fig 99) indicates the shed had a double-pitched roof oriented at right-angles to the sawmill.

Travelling Saw (building 65)

The 1926 factory plan (Fig 9) identifies building 65 adjacent to the sawmill as 'Travelling Saw'. According to George Shackley, the building was actually a shed, open-ended towards the north-west beneath a zinc (?galvanised iron) roof; it housed a circular saw for cutting planks and was powered by an overhead driveshaft from the sawmill (information from Mike Davies-Shiel and Ron Mein). The shed must have been constructed between 1888 and 1911 - the survey dates of the two OS maps - as it appears on the second edition map but not the first (see Figs 7 and 8).

The site is now used as a stance for a modern static caravan, but the building's concrete floor and most of the walls survive. The field evidence (Fig 100) suggests that the latter were dwarf walls, 0.77m high, retaining ground which rises towards the north and east. They probably supported a barrel-shaped roof structure above: both the north-east side and south-east end walls are of single-skin, brick, construction, and in addition the long wall is capped by a fillet of concrete in which are preserved at least two post voids, 0.2m in diameter and 3.3m apart between centres, penetrating into the ground behind. The bricks bear the imprint 'FURNESS BRICK CO L BARROW'. The south-west side wall is now mostly missing apart from a short length at its southern return where it also retains rising ground; this wall is rendered, but unlike the other two, appears to be constructed in stone raising the possibility that it is part of an earlier structure (although no building is shown at this location on any of the

earlier maps or plans). The rendered wall now merges with a modern dry-stone wall after 2.86m - the latter erected as part of the landscaping for the caravan stance - but the modern wall soon turns away towards the west and the course of the original stone wall re-emerges from beneath it as a low footing which can be traced for a further 3m before it is truncated by a narrow concrete slab, also part of the modern caravan stance. A slight, rectangular, plinth in the original concrete floor close to the south-east end of the caravan and about two-thirds of the way down the length of the building, retains two sawn-off metal holding-down bolts 0.8m apart. It is clearly a machine fixing (perhaps one end of the rack bench for the saw); however, if so, evidence for a similar fixing marking the other end of the bench is presently obscured beneath the caravan. The surviving brick walls show that building 65 originally measured 13.57m by 4.37m internally.

Stave-Drying Shed and associated boiler house (buildings 67 and 66)

The key to the 1926 factory plan (Fig 9) identifies a small, two-celled building (nos. 66 and 67) situated opposite the lower stove house, as 'Boiler House' and 'Drying Shed for Timber'. Additional information comes from George Shackley who remembered that the building was for drying staves destined for the cooperages (information from Mike Davies-Shiel). The building must have been erected after 1911 because it is not depicted on the OS second edition 25-inch map (Fig 8). EH has found no information on the type of boiler or heat-exchange system involved.

It is unclear if anything survives of this building. The present survey found no structural remains at the position indicated on the factory plan (which is an area of thick scrub vegetation now partly obscured by material dumped in the 1960s to help shore up the side of the heightened headrace), but did identify traces of what appears to be a twin-celled construction a few metres to the north. This feature is manifested on the ground (Fig 142) as a slight, sub-rectangular depression divided into two parts, with sides marked by earthen scarps apart from a short length of brickwork visible at the eastern corner close to the tram line to the lower stove house; the interior is heavily masked by outwash from a nearby break in the side of the sawmill leat, although probing indicated the presence of concrete or similar hard flooring material beneath the silt. At *c* 7.8m by 6.5m the observed feature is somewhat larger than the building shown on plan, but it seems likely that the two are indeed one and the same. The alternative is that the observed feature is a wartime structure.

Stave-Hollowing Shed (building 17b)

According to George Shackley, in the 1920s the northern half of a two-celled building against the south-west wall of building 17, housed a stave-hollowing machine designed to cut a depression in the centre of barrel staves. The machine was at that time powered by a water turbine situated in the southern half of the building, which also accommodated the works' dynamo; there was reportedly insufficient power in the turbine to operate both dynamo and stave-hollower simultaneously (information from Mike Davies-Shiel). The date the stave-hollower was acquired is uncertain, but the building in which it stood can be dated on OS map evidence to between 1888 and 1911 (compare Figs 7 and 8), and the turbine reported by Shackley was only bought by the company in 1910 (section 4.2 above). The later map suggests that the half of the building accommodating the stave-hollower was little more than an open-sided shed.

The 1926 factory plan (Fig 9) appears to treat the building as part of building 17, described in the key simply as 'store for casks etc'. For the purposes of the present report, however, the stave-hollowing shed will be numbered 17b, and the other half of the building containing the turbine and dynamo, 17a (Figs 139-41); the latter has already been described in detail under electricity generation (section 6.2.1 above).

In 2004 when the site was surveyed by EH, the site of building 17b was heavily overgrown and masked by dumping, and field inspection found no visible surface trace of any structure at this location. The area was subsequently cleared for car parking in 2005, however, revealing a concrete floor 0.27m lower than that in building 17a attached. Because the floor was revealed only after the archaeological survey had been completed, it is not shown on Fig 142.

Cooperage no. 1 / Box-making Shop (building 2)

Cooperage no. 1 stands immediately south-west of the saltpetre-refinery complex. The building is shown on the 1846 plan (Fig 4), although it is not until 1863 that it is first identified as a cooperage (Fig 6), a use it still had in 1928. Evidently erroneously, the building depicted on the 1863 sale plan is at right angles to its orientation not only on the 1846 plan, but on all later maps and plans (Figs 7-9), indicating that, as in other cases (section 4.2 above), the sale plan is in error. Very little other documentary information is available, although George Shackley remembered the building functioning as a box-making shop rather than a cooperage in 1928 (information from Mike Davies-Shiel). It was converted into a block of three garages following closure of the gunpowder works in 1935 (Fig 103).

Fig 103. Cooperages nos. 1 (at right of frame) and 2 (left of frame), viewed from the north; both are now converted into garages. Cooperage no. 3 is just visible in the background. (NMR DP006425)

The cooperage was a single-storey rectangular building of slate rubble, gabled to north and south, with a slate roof. Its interior was stripped out and its front (east) wall rebuilt when it was converted into garages; the interior is now divided by two breeze-block walls, and the front wall has three wide openings all with concrete lintels and up-and-over metal garage doors. The gable end walls and the rear wall, however, retain features from the industrial use of the building. The south gable wall has a central projecting stone chimneystack with good quoins which has been lowered and no longer rises above the level of the eaves. Inside, the fireplace in the stack has a wide segmental brick arch over the fire opening which has been blocked in brick, a small circular hole suggesting that a stove utilised it after it was bricked up. The north gable wall (Fig 103) also has a projecting chimneystack, but it is set slightly off-centre towards the west and has a stone base which narrows and thins back before it is instead built of red brick. The brick stops below the apex of the gable, and has inclined stone capping. The walls to either side of the chimneystack are heavily whitewashed, and belong to an addition which has been demolished; there is no fireplace opening in the outer face of the chimneystack, however, which must therefore be in the interior of the cooperage

(not seen). The rear wall of the building has four blocked openings with stone lintels, three of them former windows, the fourth, close to the south corner, being a blocked doorway with a concrete threshold. The base of the doorway is set above ground level and must have been served by steps. There are suggestions of another blocked window between the first two certain blocked windows from the north end. This irregular pattern of fenestration together with the evidence for two end fireplaces, suggests that the interior was once subdivided.

Cooperage no. 2 (building 3)

Cooperage no. 2 stands slightly south of no. 1, and like the latter, is shown on the 1846 plan although there is no confirmation that it functioned as a cooperage before 1863 (compare Figs 4 and 6). According to George Shackley it had become a foreman's office and first-aid room by 1928 (information from Mike Davies-Shiel; see also this section below). Since closure of the gunpowder works, it has been converted into a block of two garages (Fig 103).

The surviving structure is a single-storey rectangular building of slate rubble, gabled to north-east and south-west, with a slate roof. Its front (north-west) wall now contains a pair of wide garage doorways with slate-hung timber lintels and metal up-and-over doors. The interior was not seen by EH, but earlier gunpowder-period features are, close to the north corner, a probable doorway cut by the eastern jamb of one garage doorway, and a blocked doorway of conventional width, with a large slate lintel, set off-centre to the north in the south-west gable wall. There is no external evidence of chimneys.

Cooperage no. 3 (building 5)

Cooperage no. 3 lies on the south side of Bigland Road on the northern edge of Low Wood hamlet. As with cooperages nos. 1 and 2, it is first identified as a cooperage on the 1863 sale plan (Fig 6) although the building existed by 1846 (Fig 4). Given the positions of the four cooperages, it is probable that it is one of the two cooperages described in the schedule of the 1863 indenture (section 4.2 above) as 'new', the other being cooperage no. 4 (see below). Later map evidence suggests that no structural alteration was made to the building during the lifetime of the gunpowder works, although the OS second edition 25-inch map (Fig 8), revised in 1911, does depict a water tank outside its north-west wall which is not portrayed on earlier maps. George Shackley suggested that this trough was used to soak bundles of barrel hoops imported from Japan. The tank was visible until recently (Fig 104a),

Fig 104. Two views of cooperage no. 3: a (left)showing the water tank outside the building in 1968. (Davies-Shiel Collection, copyright reserved). b (right) the present building from the south-west, now a house called 'Roughwood'. (NMR DP006428)

but has now been walled round and filled with soil to create a flower bed. The building became a smoking-room for the male workforce in 1928 (information from Mike Davies-Shiel), and since the works closed it has been converted to a cottage called 'Roughwood' (Fig 104b). The conversion involved considerable alteration to the structure.

The former cooperage is a single-storey rectangular building built of slate rubble, gabled to north-east and south-west, with a slate roof. It originally had only one fireplace, set in a stone chimneystack which projects from the south-west wall and is clearly shown, though slightly attenuated, on the 1846 plan but not on later maps and plans. The original fenestration of the front (north-west) wall has been lost because of the size of the new windows, but more survives at the rear which originally had a doorway and three windows, the doorway being in the second bay from the south corner. The windows were deep, perhaps to admit light and ventilation to the interior: one has been blocked and the other two, though still windows, have blocked lower openings. The blocked window has had its lintel removed, but the thin slate water-tabling over it survives. The other two original windows both have timber lintels under similar slate water-tabling, but the timber is slate-hung for protection from rainwater. The former doorway - which has a timber lintel - has been converted into a window, having been replaced by a new doorway set within a porch against one end of the north-east gable wall. There appears already to have been a doorway in this wall, next to the new one, suggesting that the interior was originally divided into two parts capable of separate entry.

The conversion of the cooperage into a cottage involved changes to the doors and windows as noted above. The interior was subdivided and a new fireplace inserted in the north-east wall: its red-brick stack has a three-course cap, the middle course of which is cogged.

Cooperage no. 4 (building 4)

This cooperage, like cooperage no. 3, lies south of Bigland Road on the northern edge of Low Wood hamlet. It is later than the other three cooperages at the works, since it is first depicted on the 1863 sale plan (Fig 6); it is also the largest. It was probably built *c* 1860, because the schedule in the 1863 indenture (section 4.2 above) describes two of the four cooperages at the works as 'new'. The building ceased to be used as a cooperage in 1928 and was converted into a recreational facility for the workforce as part of ICI's modernisation of the factory (information from Mike Davies-Shiel). A letter box was erected outside it during the reign of King George V (1910-36). The building is now a domestic residence (no. 11 Low Wood), called appropriately 'Coopers Cottage' (Fig 105).

Fig 105. Cooperage no. 4 from the north-east, now a house called 'The Coopers'. (NMR DP006426)

The cooperage is a rectangular, single-storey building, gabled to north and south. It is raised over an inaccessible basement necessitated by the fall of the land, which is ventilated front and rear through small openings with cast-iron lattice-work vents. It is built of slate with coursed-in quoins and a slate roof, and is eight bays long. The front (east) elevation has a doorway in the fourth bay from the north end; the opposing doorway in the rear elevation was originally a window. Apart from one rear window which has a lintel renewed in concrete, all openings have substantial slate lintels, and their number and spacing are not dissimilar to

those of the cooperage at the nearby Blackbeck Gunpowder Works (Dunn *et al* 2005, 111-12). The interior seems to have had just one fireplace originally, located at the south end, its substantial stone chimneystack rising above the roof and having a slate weathering course just below its cap.

Alterations to the building which post-date its use as a cooperage saw a rear doorway (which opens on to an external flight of steps) created from the window opposite the front door. The steps have concrete treads resting on an outer stone wall and on an inner breeze-block wall built against the original rear wall of the cooperage. A second chimneystack, similar in size and form to the original one, has been inserted in the north wall.

Carpenter's Sheds (buildings 19 and 20)

The key to the 1926 factory plan (Fig 9) identifies buildings 19 and 20 at the southern corner of the works as 'Carpenters Shed[s]'. Both had been in use as such since at least 1863, since the sale plan (Fig 6) names each as 'Joiners'. Building 19 - which is a narrow building built against the north-east gable wall of the 'large' charcoal barn of the former ironworks (building 102, section 6.1.2 above) - appears to have been constructed only a few years prior to 1863 as it is not shown by the 1846 plan (Fig 4). Building 20, on the other hand, existed by 1796-9, although a small outshot had been added to the centre of the rear wall by 1846 (compare Figs 3 and 4) thus converting a rectangular building into a T shape.

Building 19 is constructed of slate rubble beneath a gabled roof. It has latterly been remodelled, and is now a garage entered from the modern yard associated with the dwellings formed within the former barn to which it is attached.

Building 20, however, is now ruinous with the interior and standing masonry heavily obscured by undergrowth and modern dumping. Much of the extant masonry has already been described in connection with the building's earlier use as part of the ironworks (stables, section 6.1.2 above). The rear (north-east) wall is best preserved, and exhibits a number of butt joins and blocked window or doorway openings (Fig 18), although the phasing is hard to determine because of the obscuring vegetation. The outshot no longer survives, blocking indicating that it may have been demolished while the building was still in use.

Wood Stores (buildings 9 / 9a and 10)

The 1926 factory plan (Fig 9) identifies two wood stores: one (building 9) situated at the southern end of the site opposite what was then the charcoal store (building 8); and the other (building 10) opposite the sawmill (building 45). Map analysis shows that building 9 existed by 1888 and had been extended slightly to the north-west by 1911, whilst building 10 was a later construction erected sometime between those dates (compare Figs 7 and 8); it also indicates that building 10 was re-constructed and substantially reduced in size after 1911 but before 1926(compare Figs 8 and 9). The two versions of building 10 are accordingly distinguished below by the suffixes mark I and II. It is just possible that building 9 existed as early as 1863, for the sale plan (Fig 6) depicts a building of the same general shape and dimensions squeezed rather awkwardly into the space between the boundary wall of the later licensed area and building 8. Given that this plan is known to have errors and inaccuracies (section 4.2 above) it is tempting to think that the building shown represents simply a

misplot of building 9; however, it will here be distinguished as building 9a. The OS second edition map (Fig 8) suggests that both buildings 9 and 10 were purpose-built as wood stores, for each is shown with at least one open side, but according to George Shackley by the 1920s each served a specialised function: building 9 was used as a store for planks destined to be made into cog teeth, whilst building 10 mark II stored timber for barrel staves, *etc*. Shackley also states that the latter building had a zinc (?galvanised iron) roof (information from Mike Davies-Shiel).

None of these building now survives. Building 10 mark II must have been demolished very shortly after the works closed, for its site lies beneath the row of wartime Nissen-hut bases (section 6.3.1 below) opposite the sawmill. Aerial photographs suggest that building 9 had also disappeared by 1945 (NMRC 106G/UK653 frame 3112); its site now lies beneath the massive embankment retaining the leat to the hydro-electricity station, and no trace is visible on the surface.

Sawpit (building 6)

The only evidence for the existence of a sawpit at the works is the 1926 factory plan (Fig 9), which locates it adjacent to the short tramway spur leading from the northern wing of the saltpetre refinery. The indicated site is now used as allotments, and no surviving evidence for a sawpit was found by EH during the present investigation.

Other Ancillary Buildings

Sieve House (building 78)

Sieves played an important role in the manufacture of gunpowder, being used to separate powder grains into different size ranges and eliminate under- and over-sized particles. Sieve cloth was made from fine bronze, brass or copper wire, or for the finest meshes from silk (and later nylon) mono filament. They were comparatively fragile, and had to be carefully stored when not in use to prevent damage; metal sieves had to be stored dry to prevent rust (Patterson 1995, 1-2). Sieves also had to be stored in a clean environment to prevent contamination with grit which might induce sparking - leading to an explosion - when in use: the presence of grit in a sieve brought in from a store whose walls were unlined was put forward as a possible cause of an explosion in the corning house at the nearby Elterwater gunpowder factory in 1878 (Explosives Inspectorate 1878). The principal uses of sieves were: in the preparing house to ensure that raw ingredients were sufficiently ground up; in the corning house where press cake was broken down into granules; and in the dust house where remaining under-sized particles were removed at the end of the manufacturing process.

The 1863 sale plan (Fig 6) identifies a small building situated on the river bank midway between the main tailrace and the wheel-pit to preparing house no. 1, as ‘Sieve Ho[use]’. The building did not exist in 1846 (compare Fig 4), but had apparently stood for several years prior to 1863 because it is not described as new in the schedule in the 1863 indenture (section 4.2 above). It presumably stored sieves for use in the adjacent preparing houses. The building seems to have survived until 1886, when it was replaced by an accumulator/ pump house to power the presses in the new cartridge-press house converted from preparing house no. 1 at the same time (section 6.2.4 above). As later maps and plans (Figs 7-9) show the pump house on a slightly different site to the sieve house, the latter was most probably demolished, not converted.

The sieve house is identified as building 78 on the phase diagrams (Figs 134-8) in the present report, although it is possible that for most of its life it possessed the factory number 21 and that at demolition the number was simply re-allocated to the pump house which replaced it. There is no evidence for the existence of a dedicated sieve house which could have served preparing house no. 2 after 1886. It is likely that sieves for use in the two corning houses at the works had always been, and continued to be, stored close to those houses, possibly in buildings 44a and 74 (this section above and section 6.2.7 below).

Miscellaneous Stores (buildings 17, 43 and 54)

The 1863 sale and 1926 factory plans (Figs 6 and 9) both record the existence of a number of general storage buildings, namely buildings 43, 54 and 17. All three had other uses before they were downgraded to stores, however: prior to 1861, buildings 43 and 54 were a packing house and expense magazine respectively, and before 1918, building 17 was a charcoal store. Each has been adequately described in the section discussing its original function (sections 6.2.3 and 6.2.2 above).

Fire-Engine House (building 16)

Gunpowder works obviously needed fire engines to fight fires. Lowwood probably acquired its first engine in 1802, and certainly purchased a second in 1862 (section 4.2 above). However, the 1875 Explosives Act placed a legal obligation on gunpowder works to hose out the interior of danger buildings prior to any maintenance work, so as to remove or at least damp down residual powder: such tasks were also undertaken by the fire engine.

The location of the building in which the fire engines were stored at Lowwood is unrecorded before the 1926 factory plan (Fig 9), whose key names building 16 immediately north of the saltpetre refinery as 'Fire Engine House'. This house had been sited in the same general location since at least 1914, for in January of that year the roof of the building was reported as damaged by flying débris from a blast in a nearby quarry, which also caused damage to the saltpetre house (HF LW/959/392a). The siting makes excellent sense logistically, for building 16 lies adjacent to the entrance to that part of the works where all the danger buildings were located, enabling the engines to be deployed rapidly to wherever needed in the event of fire or explosion while at the same time being far enough away not to be at risk from blast damage themselves. Although incapable of definite proof on the available evidence, it seems likely that building 16 had served as the fire-engine house since 1802; the building certainly existed by 1846 (Fig 4). A fire-engine house is included amongst the assets listed in the schedule in the 1863 indenture (section 4.2 above), but unfortunately is not identified on the accompanying sale plan (Fig 6).

RAF aerial-reconnaissance photographs curated at the NMRC show that building 16 was still extant and roofed in 1950 (*eg* 541/525 frames 3306-7). It was buried shortly after beneath the massive embankment retaining the re-routed leat to the hydro-electricity station, but field evidence suggests it was not completely demolished for the face of what should be part of its south-west wall is still visible retaining the foot of the embankment behind the modern garage belonging to the 'Charcoal Store' (Fig 142).

Offices and Counting House (buildings 101a and 101c)

Tyler claims (without giving his source) that offices existed right from the time the works opened in 1799 (section 4.2 above), but the earliest evidence which EH has found for their existence and location is the 1846 plan (Fig 4). The evidence of this plan, together with that of 1863 (Fig 6), indicates that by the middle of the 19th century office accommodation had been created by the selective rebuilding of either end of the former iron-ore store. The 1926 factory plan (Fig 9) identifies the two office blocks as buildings 12 and 13, but for reasons outlined in section 6.1.2 above, they have here been renumbered buildings 101c and 101a respectively. Both stand in a very appropriate position for such a use, close to the entrance to the works.

Cartographic and structural evidence (Fig 3 and section 6.1.2 above) indicate that the iron-ore store was originally a rectangular, six-bay building terraced into the hillside. The 1846 plan, however, identifies the north-east end of the building as a 'Counting House', and depicts it as a separate block projecting beyond the original width of the building on both the up and downhill sides. The 1863 sale plan shows the block doubled in length, and also portrays a separate block at the other end of the range as an 'Office', although in this case projecting only on the downhill side of the building. Both blocks also appear on the 1888 and 1911 OS maps (Figs 7 and 8), although the north-eastern example is shown with a downhill projection only; the 1926 factory plan reverts to the more precise shape of the sale plan. The cartographic evidence thus indicates that about half of the iron-ore store was eventually converted to offices by the gunpowder company, and this is confirmed by the physical evidence of the building. One effect of the change of use was to give the building a distinct front elevation since the offices were all entered solely from the uphill side. The basements - which were incidental to the creation of the offices, and not connected with them internally - were all entered from the downhill side of the building: they are likely to have been used as peat houses by residents of the hamlet, as they are today. Since the closure of the works, the whole upper level of the building has been converted into houses.

The office accommodation at the north-east end of the building was built in two stages. The first office - which probably dates from the early years of the gunpowder company and was certainly in existence in 1846 - was created in bay 1 of the former iron-ore store. It was a single-bay, two-storey structure, gabled to the north-east and south-west, and with its uphill and downhill walls rebuilt in advance of those of the original store which were both demolished. The uphill wall was probably taken down and built anew because of the extent of the rebuilding required to insert a doorway and window in place of what would have been solely a pitching eye: the doorway is now obscured by a porch and toilet added in the 1920s (Fig 106), but the window beside it has a long irregularly shaped slate lintel. The downhill wall was presumably taken down and rebuilt further out simply to create more room; the new wall (Fig 16) has a central basement doorway and, above it, a first-floor window lighting the office. The basement

Fig 106.
The addition to the north-east block of offices within the former iron-ore store, in 1929.
(Patterson Collection, © English Heritage.NMR)

doorway has a roughly-squared slate lintel, but the first-floor window must, given its size, type of frame and slate-hung timber lintel, be an enlargement of an earlier, smaller window. As noted earlier the north-east gable wall retains a great deal of the masonry of the gable wall of the iron-ore store, but as well as building out from this, much of the upper part of the original gable was taken down and a wider, taller gable raised up over it in good quality coursed slate rubble. The roof, supported by two purlins on each side, now has a renewed slate covering. The south-west gable wall of this first office must incorporate the dividing wall of the earlier iron-ore store. The office was heated by a fireplace in the south-west wall, the single-flue stone chimneystack of which rises above the apex of the roof. The basement beneath it has three transverse beams supporting the joists which carry the floorboards of the office above. It is a single, undivided room which is now whitewashed and has a concrete floor, both of them obscuring any evidence of former reddening from the iron ore once stored here. An inserted narrow doorway just inside the front door and only 0.52m wide, leads through the side wall into the basement of bay no. 2.

Between 1846 and 1863 the former ore-store was further modified, in two stages, so as to provide additional office accommodation. The first stage involved the enlargement of the existing office, and was created by rebuilding bay 2 adjoining the south-west side of that office. The addition was similar in size to its predecessor. The downhill side of the new office was rebuilt further outwards to line up with the wall of the existing office (Fig 16): the new wall is of slightly smaller rubble than the earlier one, and the two walls are well keyed-in; there is no straight joint between the two, but enough stones line up for its position to be visible. The downhill wall also has a small, blocked ventilation opening into the basement, but no doorway since it was reached internally from bay 1. A tall, wide first-floor window with a slate-hung timber lintel must replace an earlier, smaller window. The second office was not extended out on the uphill side, however: the 1929 photograph (Fig 106) shows the uphill rubble wall – which is actually the wall of the original iron-ore store – partially hidden by a new single-storey addition incorporating a porch and a toilet and built of rock-faced pre-cast concrete blocks. This photograph shows a chimneystack which no longer survives rising above the ridge, indicating that the new office was heated. The roof over the second office has been renewed in slate.

A third office - which on stylistic grounds must be the later of the two erected between 1846 and 1863 - was built at the south-west end of the former iron-ore store (Fig 16). It totally replaced that end of that building, as the evidence of the basement walls indicates (section 6.1.2 above). Its walls are entirely new build, of good quality coursed slate rubble of varying sizes with well coursed-in quoins and a slate roof. It has a tall ground floor, but no attempt was made to create a basement: there is simply an inaccessible, ventilated void. The office itself is quite eye-catching, as befits its position on the approach to the gunpowder works. It has timber lintels with slate hood moulds over the off-centre front door in the uphill wall, the window at the uphill end of the gable wall (the other window in this wall is a modern insertion), and the wide window in the downhill wall, and its roof is supported on purlins with shaped ends, two per side. A slate chimneystack, later heightened in red brick, rises above the apex of the end gable wall. Inside, the front door opens into a lobby with a door on the left into a former closet and another ahead into the office proper. These rooms are tall, and the doorway into the office and the windows within it and in the closet have identical moulded architraves in the form of a cyma-moulding cut on the splay combined

with two fasciae separated by a smaller cyma moulding. The door into the closet from the lobby is modern, but that into the office is original and has flush-beaded planks on both sides, which is also the form of the window shutters to the wide front window. An early 20th-century cast-iron 'CHATTAN SPECIAL' range is set in the fireplace in the projecting chimneybreast in the south-west wall, and a modern cupboard overlaps the left-hand side of the chimneybreast. A timber post runs up the centre of the north-east side wall of the office, and has an expansion close to the top; its purpose is uncertain.

A pair of cast-iron gate piers with square-sectioned bases, slender tapering octagonal-sectioned shafts and moulded caps stand between the uphill corner of the north-east office and building 100 to the north (Fig 107); the existing wrought-iron gate is not original. Railings to either side have been lost, but the gate was clearly meant to mark an entrance into the gunpowder works from the road outside it. A wooden box attached to the wall of the office just on the works side of the gate, has a sloping roof projecting out over an outer face fashioned as a hinged flap (Fig 108); it is alleged to have been where keys to the various parts of the factory were passed out to workers (information from Ron Mein).

Fig 107.
The entrance into the works between buildings 100 and 101a, showing the cast-iron gate piers and key-box (arrowed) on the wall.
(Christopher Dunn, July 2005)

Fig 108.
The key-box in the gable wall of the north-east office block.
(Christopher Dunn, July 2005)

The entire ground floor of the office building was converted into housing after the closure of the gunpowder works in 1935. The central narrow part, which preserved the depth of the original iron-ore store, was totally rebuilt in brick which is roughcast externally and stands on a concrete beam laid on top of the masonry of the lower walls of the store. The windows all have concrete sills, and one of the front windows was once a doorway. The three rooms in the centre are divided between the houses at either end: two belong to the south-west house (Bigland Foot), which had one extra window inserted in its end gable wall on its conversion from an office, while the other one goes with the house to the north-east (Bracken Rigg), which has a small inserted window in the uphill wall next to the small 1920s extension. The wall in which this window sits, as well as the extension, were rendered along with the central rooms.

Foreman's Office and First Aid Hut (building 3)

According to George Shackley, after modernisation of the works in 1928 the former cooperage no. 2 doubled up as offices for the site foreman plus a First Aid hut (information from Mike Davies-Shiel). The history and architectural form of the building have already been described (this section above); there is nothing in the surviving fabric which confirms, or can be related to, this reported change of function.

Recreational facilities (buildings 4 and 5)

George Shackley also informed Mike Davies-Shiel in correspondence he sent the latter, that cooperages nos. 3 and 4 south of Bigland Road were converted in 1928 to, respectively, a smoking-room and recreation hall. The former was where the male workforce could indulge in a lunchtime cigarette (once they had changed out of their powder clothes), the latter contained a billiards table, *etc*. The recreation hall is presumably the same as the 'reading and recreation room' which was officially opened by Mrs Cowtan, the wife of the works manager, on 3 February 1928 (Imperial Chemical Industries 1928, 214). Again, the architectural form and evolution of each building has already been outlined in the discussion of their former purpose (this section above), and there is nothing that needs to be added here.

Dining-Room (building 11b)

According to George Shackley, the 1928 modernisation of the factory also involved the conversion of the area above the new wash and change house at the northern end of what is now the Clocktower complex into a works canteen or dining-room (information from Mike Davies-Shiel). This part of the building is now in use as showrooms, and during investigation EH discovered no physical evidence pertinent to its use as a dining-room. The general architectural form and evolution of the Clocktower complex have already been described in section 6.2.2 above (saltpetre refinery).

Privies (unlocated, and building 73)

No privy is named on either the 1863 sale or 1926 factory plans. Privies must have existed at the works, however, and it is likely that six small structures depicted by the OS in 1888 and 1911 (Figs 7 and 8) - but which for the most part do not appear on the 1863 or 1926 plans - are examples. However, as they cannot be positively identified they are described in more detail under unidentified gunpowder buildings in section 6.2.7 below (buildings 68-72 and 75). The majority appear to have been constructed only after 1861; none now survives.

Fig 109. The privy (building 73) to the reel and glaze house, from the south-west. (NMR DP003487)

An extant stone structure, not recorded on any of the maps and plans but which has every appearance of being a privy, was identified and recorded by EH during the course of survey, however (Fig 109). It stands within a small quarry close to the southern end of the now collapsed tramway bridge across the Leven. It is now roofless, but measures 1.2m by 1.09m internally and originally had a double-pitched roof. A small hole at the base of the south-east wall near the southern corner was presumably to enable the slops bucket to be removed and replaced from

outside the building. Entry was by a door in the north-east wall, suggesting that the privy was intended for the workers in the nearby reeling, dusting and sizing house to which it appears to have been connected by path running above the river bank (Fig 142). The building obviously cannot be earlier than the quarry in which it sits, but neither it nor the quarry is shown on any of the historic maps or plans of the works. This fact, together with its comparatively good state of preservation, suggests it is a late structure probably erected after 1926.

6.2.7 Unidentified Gunpowder Buildings

Building 43a

The 1846 plan (Fig 4) shows a T-shaped structure situated in the approximate middle of the works close to the river bank, immediately behind the building labelled 'Packing Room'. The tail of the 'T' was probably little more than a porch, indicating that the building was entered from the north-east. Although it is unnamed on the plan, the building's proximity to another, danger, building points to a functional link between the two, and indeed the suggestion has already been made ('early' packing house, section 6.2.3 above) that it may have acted as a store for empty casks. It had disappeared before 1863 (compare Fig 6), most probably rendered redundant and demolished *c* 1861 when packing was transferred elsewhere within the works. Obviously, it was never covered by the sequence of factory building numbers in use in 1926, but for purposes of the present report it will be referred to as building 43a on account of its apparent close association with building 43.

EH found no above-ground trace of the building during survey, although the area is now thickly overgrown and ephemeral evidence may easily have been overlooked.

Building 68

The OS first and second editions 25-inch maps (Figs 7 and 8) both depict a small building immediately north-west of the wood store closest to the Clocktower complex (building 9, section 6.2.6 above); the earlier map shows it as freestanding in 1888, but by 1911 (the survey date of the later map) building 9 had been extended to butt up against it. The structure does not feature on the 1926 factory plan (Fig 9). In consequence, there is no documentary record of its function, but as it was only about 2m square it is most likely to have been a privy for the use of workers in nearby buildings. Although not shown on the factory plan, it seems inconceivable that it was not then still standing and in use. For the purposes of the present report it will be numbered building 68.

The site lies beneath the massive embankment erected in the 1950s in association with the hydro-electricity station, and EH found no trace of the building during investigation.

Building 69

The only evidence for the existence of what, for the present report, has been numbered building 69 is the OS first edition 25-inch map (Fig 7), which shows that in 1888 a small structure was located just north of the angle between the headrace and the leat to incorporating mills 33-38. Although its function is undocumented, the similarity in size to building 68 suggests it was a privy, probably for the use of workers at the sawmill and/or lower stove house. Its omission from the OS second edition map might point to it having been demolished before 1911, but it is equally possible that its very small size simply

precluded it from depiction. For the purposes of the phase diagrams (Figs 136-41) in the present report, it has been assumed that it originated at least 20 years before its depiction on the OS first edition map, and also that it survived until closure in 1935.

The site indicated by the map lies beneath what is now the edge of a drainage lagoon fed by seepage from the main headrace (Fig 142), and no trace of the building was found by EH during survey.

Building 70

The OS first edition 25-inch map (Fig 7), surveyed in 1888, is likewise the only source of evidence for another small structure (here called building 70), of similar dimensions to buildings 68 and 69 but this time sited close to the river bank and north of the low press house mark II. As with both those other examples, building 70's size and location suggest it was a privy, most probably in this instance for the use of the men in the press house. Again, its omission from later maps and plans might suggest it had been demolished before 1911, but for the purposes of the phase diagrams (Figs 136-41) in the present report it has been assumed that it survived until closure in 1935. The earliest possible date for its construction must be 1861, as the land on which it stood only became part of the works in that year.

The mapped siting corresponds very well with a small stone structure whose footings survive adjacent to what is probably the outfall of the tailrace from the sawmill behind the low press house (Fig 142)

Building 71

The only record for the existence of what is here termed building 71 is again the OS map surveyed in 1888 (Fig 7), which portrays a small structure *c* 2m square close to the river bank between expense magazine no. 1 and the lower corning house. As with other structures of this size, it is most likely to have been a privy. It was probably erected in the 1860s for it is lies on land only leased by the factory in 1861, and as with other privies is likely to have remained in use until 1935 even though not depicted on maps and plans after 1888.

On the ground, the site is heavily overgrown by rhododendrons and no upstanding evidence of the building was found during investigation. The indicated site, however, lies close to, or on the line of, a slight scarp overlain in places by piles of stone rubble (Fig 142); the source of the rubble is unclear, but conceivably some may have originated from the demolition of this building.

Building 72

The first and second edition 25-inch maps of the OS (Figs 7 and 8) show that between at least 1888 and 1911 a small structure existed north of the tram line linking the glazing house and 'later' dust house/'final' packing house (building 49). Its original factory number is not known due to its omission from the 1926 factory plan (Fig 9), but for present purposes it will be given the building number 72. Its size (*c* 2m square) and location are again typical of other buildings previously interpreted in this report as privies (buildings 68-71 above). It must have been built after 1861 because it is situated on land only leased by the company in that year; although not depicted on the 1926 factory plan, is likely to have remained in use until 1935.

The mapped position of building 72 corresponds closely on the ground with a low overgrown mound of stone rubble (Fig 142).

Building 75

The earliest evidence for what is here termed building 75, which stood close to the outfall of the main tailrace, is the 1846 plan (Fig 4). This suggests that the structure may date from, or very soon after, the opening of the works in 1799. Its small size (*c* 3m by 2m) and general positioning both support identification as a privy (probably for the use of workers employed in the nearby charcoal retorts). The building appears on the OS first edition 25-inch map (Fig 7), and was therefore still standing in 1888. Although not depicted on later maps and plans, the present report has assumed for phasing purposes (Figs 132-40) that it remained extant until *c* 1926 by which time the charcoal retorts had become redundant.

The indicated site now forms part of the lawned gardens around 'The Charcoal Store' (Fig 142), and no physical evidence for the building was seen by EH during investigation.

Building 76

A small building of unknown function is depicted on both the first two editions of the OS 25-inch map (surveyed in 1888 and 1911) and the 1926 factory plan (Figs 7-9) standing close to the river bank immediately north of the lower corning house mark III. As the latter plan in particular does not name the structure, the likelihood is that its function was in some way tied in with that of the adjacent corning house. All three maps depict the building as standing at the end of tramway spurs connecting the corning house with the glazing house and expense magazine no. 1. This raises the possibility that it was a small covered shelter where press cake sent by bogie from the expense magazine could be offloaded and wheelbarrowed into the corning house, and/or corned powder loaded for onward transit to the glazing house. It is unclear if the building was demolished in 1928 alongside the mark III corning house, or continued in use servicing the replacement mark IV version. For the purposes of the present report it has been numbered building 76.

No trace of any structure which could correspond to building 76 was found by EH during survey, even though the previously thick ground vegetation around the mark IV corning house was cleared prior to investigation.

Building 77

The OS second edition 25-inch map (Fig 8), revised in 1911, portrays a long, thin rectangular building adjacent to the sawmill leat and in line with the travelling-saw shed (section 6.2.6 above); as it does not appear on either the OS first edition map or 1926 factory plan, it must have been erected after 1888 and demolished before 1926. It is here referred to as building 77. Although its function is undocumented, its position in relation to the saw shed plus the fact that the map depiction of it shows it as open-sided towards the north-east, point to it having been a wood store.

The area in which it lies is now mostly overgrown and partly flooded by water seeping from the sawmill leat, and EH found no evidence for this structure during investigation; moreover, its north-western end would seem to have been destroyed by the quarrying of the rising ground behind the sawmill (section 6.2.10 below).

Building 82

The 1846 plan (Fig 4) depicts a small structure adjacent to the south-west boundary of the small paddock or enclosure to the rear of what, in this report, has been interpreted as the stable and/or cart house to the former ironworks (section 6.1.2 above). Its function is unrecorded, and it had disappeared before 1863. It is not even clear that it formed part of the gunpowder works, but it is included on the relevant phase diagrams (Figs 132-3) in the present report numbered as building 82.

The line of the paddock boundary and probable stance of building 82 is still traceable on the ground as a ruinous and much overgrown wall line and platform, partly masked by later dumping (Fig 142).

Building 101b

Of the three historic maps of the gunpowder works which include information on the function of buildings (the 1846, 1863 sale and 1926 factory plans (Figs 4, 6 and 9)), none ascribes any function to the central section of the former ironworks iron-ore store (here numbered building 101b for the reasons given in section 6.1.2 above). This suggests that the central section never played an active role as part of the works. It may instead have been let out, possibly as a peat-house for one of the workers renting accommodation from the gunpowder company in the attached hamlet (section 6.2.10 below), as has already been suggested (offices and counting house, section 6.2.6 above).

Buildings 102b-d

The 1863 sale plan (Fig 6) shows the former ironworks 'large' charcoal barn divided into four compartments (here numbered buildings 102a-d for reasons outlined in section 6.1.2 above). The plan names the southernmost compartment (building 102a) as in use as the saltpetre warehouse, but the other three either have uses which suggest they may have been let out (cow house and stables - but for an alternative view see also section 6.2.8 below) or have no function ascribed to them (building 102d). The 1926 factory plan (Fig 9) shows all four compartments as either disused (saltpetre warehousing), or cross-hatched (buildings 102b-d) as if they were not then counted as part of the works. There is no information on what buildings 102b-d were used for at this time.

6.2.8 Transport to and from the Works

The Lowwood works was close to the coast and was hence well-placed with regard to sea-borne transport; from the second half of the 19th century it also benefitted enormously from its proximity to both the rail line between Carnforth and Barrow and a branch from it up the Leven valley. Some account of the transport of raw materials and goods to and from the works by road, water and rail has already been given in section 4.2 above, but the references are scattered. Accordingly the principal details are repeated below, drawn together into a single narrative. Two buildings which appear to have been associated with the early use of road transport are also described below: a stable and possible cart-house. Both seem to have been disused before the end of the 19th century for they are unnumbered on the 1926 factory plan; for the purposes of the present report they have been given the numbers 102c and 102b.

Road, Water and Rail

Until about the third quarter of the 19th century, saltpetre which the company purchased in London was transported either by sea or via the inland canal network to Liverpool, where it was off-loaded on to local coastal trading-vessels for onward passage to the Cumbrian ports of Ulverston (Canal Foot) and Greenodd on the Leven estuary (Fig 1). It presumably completed the final few miles of the journey to Lowwood by horse and cart. In the early period, the company could also have made use of Bigland Dock situated about 200m downstream of the works (section 4.1 above), but there is no evidence to confirm or refute this suggestion. Sulphur imported from Naples or Sicily was bought at Liverpool, and sent north to the factory by the same route. Before 1801, charcoal was purchased locally, after which it was manufactured on site from coppice wood supplied by local dealers. Apart from local orders (termed 'the country trade'), much gunpowder was sold through agents in Liverpool (where by 1800 the company had their own magazine) and therefore travelled the same route in reverse - the only difference being that vessels frequently took on cargoes directly from the company's two coastal store magazines at Roudsea as well as through the local ports (section 4.2 above). The company mainly used chartered shipping (*eg* Tyler 2002, 125-8), but later also operated its own steamer, the 'Leven' (Imperial Chemical Industries 1929, 340). Tyler (2002, 117) claims that the vessel was in service as early as 1854, but this is unlikely given that it does not feature amongst the company's assets listed in the schedule to the 1863 indenture (section 4.2 above), and is not mentioned in surviving company correspondence in the HF archive before 1879 (LW/959/008). It seems to have been used to deliver gunpowder to ports along the North Wales coast (Imperial Chemical Industries 1929, 340).

The opening of the rail link between Ulverston and Carnforth in 1858 provided the company with an alternative means of transporting both raw materials and its finished product. Rail freight was initially more expensive than coastal shipping, but rapidly became more attractive as the viaduct constructed to carry the new line across the Leven estuary was found to be a navigation hazard and also caused the established shipping channels in the river to begin to silt and change course. In consequence the company negotiated its own siding at Cark, the nearest station on the new line, some 9km from the works, and constructed an additional store magazine at Busky field only 0.5km from the factory especially to service orders to be despatched by rail. The company no doubt had its own horse and cart by this time if not before (a stable - and possibly a cart house – certainly existed at the works by 1863; this section below) for use on the everyday journeys between the works, the three store magazines, Cark Station, and the ports of Canal Foot and Greenodd, but also made use of independent carters especially for servicing country-trade orders (*eg* Tyler 2002, 108 and 123-4). In 1869 the company's Cark siding was rendered redundant by the opening of the Furness Railway's branch line along the Leven valley with its attendant station at Haverthwaite only a few hundred metres from the factory. For about fifteen years, the company continued to send and collect consignments to and from Haverthwaite station by road, but in 1884 extended the existing internal works narrow-gauge tramway system (section 6.2.9 below) across the river and into the station yard. It is likely that the company's use of sea transport for gunpowder deliveries was becoming less and less frequent by this time, for a proposal in 1879 to construct a pier at Roudsea to enable ships to continue to load directly from the magazines there irrespective of the state of the tide was not taken forward (section 4.2 above).

Stable (building 102c)

The earliest evidence for a stable at Lowwood is the 1863 sale plan (Fig 6), which locates it in the middle of the 'large' charcoal barn erected by the earlier ironworks company. It had been abandoned before the gunpowder works closed, however, as this part of the barn is shown as not in use on the 1926 factory plan (Fig 9). The latter plan gives no number for the compartment, but for present purposes it is here numbered building 102c. Since the 1863 plan identifies the adjacent compartment to the south as a cow house, however, it is just possible that the stable did not form part of the gunpowder works but was instead rented by a local farmer.

Cart House (?building 102b)

EH has found no documentary reference for the existence or location of the company's cart house at Lowwood. However, it is tempting to think that the 1863 sale plan's (Fig 6) naming of a 'Cow House' (section 6.2.10 below) in the centre of the 'large' charcoal barn erected by the former ironworks is in error for cart house, particularly as it lies adjacent to another compartment labelled 'Stable'. It, too, was disused by the time of the 1926 factory plan (Fig 9) which accords it no number; it will here be referred to as building 102b.

6.2.9 Transport around the Works

Documentary references to how powder was moved around the Lowwood factory in the course of its manufacture reveal that this was initially carried out using a combination of road and water transport. In 1869, however, both modes of conveyance were replaced by a system of man- and horse-drawn, narrow-gauge vans and wagons (or bogies as they were frequently called). An historical overview of the introduction and development of the tramway system has already been given in section 4.2 above, but the most pertinent details are reviewed again below in order to bring them together into a single narrative. Two buildings are recorded in connection with the tramway: a harness room and loose box. By 1888 a weigh house also existed to check the weight of materials as they moved around the factory. All three of these buildings are described below under the factory numbers (respectively 39, 40 and 10a) recorded for them on the 1926 factory plan (Fig 9).

Road system

Even though the use of internal road transport is not documented at Lowwood before 1868 - when a local newspaper report refers to press cake arriving at the corning house from the press house in canvas-covered tubs carried in wheelbarrows (*Westmorland Gazette* 5 Dec 1868) - this was undoubtedly the principal method by which powder was conveyed between process buildings for the first seventy years the factory was in operation. It is possible that horse-drawn carts were employed for the longer journeys, but if so the horses would have been soft-shod in brass or copper shoes to avoid the risk of striking sparks on the road surface. The road network obviously developed over time as buildings were moved or new ones added, as can be seen by comparing the 1846 and 1863 plans (Figs 4 and 6). However, there is no indication that the roads were ever surfaced or maintained in any special way to prevent the ingress of dirt or grit into danger buildings – another potential source of sparks and therefore explosions – as is recorded for example at nearby Elterwater (Tyler 2002, 176). Wheelbarrows were probably rendered largely redundant at Lowwood in 1869 (apart for conveying charges to and from the incorporating mills) when a narrow-gauge tramway

system was introduced linking many of the buildings, with motive power for the longer and/or uphill journeys supplied by horses (this section below).

Water transport

A couple of documentary references (HF LW/1863/036 and LW/958/097) indicate that before 1869 a boat was used to move powder between buildings which stood adjacent to the headrace (namely the reel and glaze house, expense magazine no. 2, and the two stoves). Although the earliest of the references is dated 1863, and specifically mentions a boat in connection with the reel and glaze house (which together with expense magazine no. 2 was only built *c* 1861), it is perfectly feasible that a boat had already been in use previously to move powder between the stoves and the 'earliest' expense magazines which also lay adjacent to the headrace. Given the headrace's restricted width and depth, the boat was probably akin to the flat-bottomed punt used at the Marsh Works, Faversham (Kent) in the 1930s (www.faversham.org/photogallery.gunpowder.asp).

A flight of stone steps which lead down into the leat behind the higher stove house (Fig 82) must mark the location where the punt was moored when delivering to/picking up from the latter building. Similar steps/mooring facilities would presumably have once existed adjacent to the sites of the lower stove house, earliest store magazines and the reel and glaze house, but at each of these locations the evidence has been lost through the collapse of the original stone walling defining the leat side and/or its replacement in concrete as part of the post-war heightening of the headrace (section 6.3.2 below).

Tramway system

Plans were first drawn up for a narrow-gauge (3 feet 6 inches (1.07m)) horse-drawn, tramway system at Lowwood in 1865. The impetus for the scheme appears to have been the Furness Railway Company's decision that year to resurrect its earlier proposal (first put forward in 1846) to construct a standard-gauge branch line along the Leven valley. However, no tracks were laid at Lowwood until after the branch line opened for business in 1869. The initial scheme for the tramway envisaged a direct link to the branch by laying an extended spur to meet the latter at Ladysyke almost 2km west of the works; this spur would also have served to connect the main part of the works with the company's outlying Busky store magazine. However, the spur was not included in the scheme authorised in 1869, most likely for reasons of cost (section 4.2 above). Instead, the system as built was confined to the main area of the works. Consignments of powder continued to travel between the works and Busky magazine, and between Busky and Haverthwaite Station just north of the factory, by horse and cart (this section above).

It was not until 1883/4 shortly after the works had been taken over by the Wakefield Company that the tramway system was extended, initially out to the Busky magazine, and again or also in 1884 by a new line up to Haverthwaite Station on land which the company owned on the Stang End side of the river. In both cases the company had to get permission for the lines to cross the public highway (section 4.2 above). Neither crossing seems to have been protected by gates or controlled by a flagman, although two metal gateposts which survive at the roadside near to Low Wood Bridge (Fig 142) indicate that the line out to the Busky magazine was gated off where it emerged from company property; the gate itself is now

lost. A similar pair of gate posts, this time with the iron gate still *in situ* between them (Fig 110), survive on the Stang End side of the river (Fig 142). The gate does not mark the edge of gunpowder company property, nor where the line emerged on to the public highway, nor even where the tramway passed out of the licensed area; the exact rationale behind it is unknown, although it must have been intended either to control access or mark a point beyond which special rules had to be observed. The line to the station crossed the river over a purpose-built bridge at Bleaberry Holme, and ascended the valley side by way of two zig-zags or reversing points where the horse had to be detached and led around its train to pull in the opposite direction; wagons made the return descent under gravity, with the horse led down separately (Quayle 1977). According to captions accompanying photographs in the Patterson Collection in the NMRC, the original bridge - which seems to have been a largely timber affair - was replaced in 1929 by one of metal girder construction, supported by a central concrete pier on Bleaberry Holme (Figs 112a and b).

Fig 110. The iron gate on the Stang End side of the river across the tram line up to Haverthwaite Station. (NMR DP006422)

The new owners also made a number of alterations to the layout of tram lines within the factory in 1883/4 in order to make traffic movements more efficient. The original track layout is recorded by dashed lines on the 1926 factory plan (Fig 9), while the altered post-1884 system was surveyed in 1888 for the OS first edition 25-inch map (Fig 7). Further alterations made between 1888 and 1911 are depicted on the OS second edition 25-inch map (Fig 8). The factory plan suggests few track changes were made between 1911 and 1926, although surviving field evidence attests to a couple of late alterations most probably dating to 1928/9 and undertaken as part of ICI's general modernisation of the works.

At least three designs of wagon or bogie are recorded. When the works closed in 1935, some of the rolling stock was abandoned on site: two box cars and an open wagon were photographed and recorded *in situ* by Mike Davies-Shiel in the 1960s (Fig 111). In 1986 both box cars were removed from the former works into the safe-keeping of the Lakeside Railway Society, and stand restored but neglected on the edge of the former goods

Fig 111. Two of the tram bogies abandoned at Lowwood, photographed in 1965: a (left) A box car. b (right) The open wagon. (Davies-Shiel Collection, copyright reserved)

yard at Haverthwaite Station, now part of the Lakeside & Haverthwaite Railway; the four-plank open wagon, however, was destroyed by a falling tree weeks before it was due to be rescued (Lister 1987). The third design of bogie – a kind of covered wagon very similar to those which salt companies used to ensure their product remained dry during transport by rail (information from Christopher Dunn) - is known only from a 1929 photograph of the low press house (Fig 58).

Since closure, the track has been lifted in its entirety, but large parts of the system can still be traced on the ground either as visible engineering works or, especially between buildings 45 and 49 and on the southern approach to the tramway bridge, as a series of sleeper impressions in the former track bed. The visible evidence mostly confirms the course of the various tram lines and spurs recorded by the historic mapping, but two lengths of tram line are not shown on any of the maps: first, an extension of the apparent short siding adjacent to the boiler house at the higher stove, suggesting it was later developed into an alternative rail route to the lower stove; secondly, a deep rock cutting leading to the southern end of the girder bridge. Both are likely to date from the 1928/9 modernisation. The purpose and dating of the first has already been discussed under stoves in section 6.2.3 above; the deep rock cutting may have been constructed to provide a more direct route (by-passing the 'final' packing house) for blasting cartridges in transit between the higher stove house and the cartridge-packing rooms on the Stang End side of the river. The girder bridge was extant until the late 1970s but has since collapsed (Figs 112c and d) and been cleared away; only its stone abutments and central concrete support now survive (Fig 142).

Fig 112.
Four views of the tramway bridges at Bleaberry Holme. Clockwise from top right: a and b. The original timber bridge and the new girder bridge which replaced it in 1929. (Patterson Collection, © English Heritage.NMR).
c. The southern end of the girder bridge in June 1966. (Davies-Shiel Collection, copyright reserved)
d. The collapsed girder bridge viewed from the south in the 1970s. (Robert Harvey Collection, copyright reserved)

Harness Room and Loose Box (buildings 39 and 40)

The key to the 1926 factory plan (Fig 9) names two small buildings located a little north-east of the charge house, as 'Harness Room' and 'Loose Box'. Both lie adjacent to tram lines, and should probably be associated therefore with the horses which pulled bogies around the system: the function of the harness room is self-evident; the loose box is where horses would have been kept during the day in between bogie movements. It is not clear where the horses were stabled overnight.

However, neither building was purpose-built for the functions performed in 1926. Both originated as mortar or proof houses, erected *c* 1862 in connection with Lowwood's fateful and short-lived excursion into manufacturing military-grade powders (section 6.2.5 above). It is possible that conversion to their new uses took place as early as 1869 (the year the tramway system was installed at the works) by which time Lowwood had ceased production of military-grade powders.

Neither building now survives. The site of building 39 is open ground, although heavily overgrown by scrub, but the site of building 40 lies beneath the westernmost of a row of five wartime Nissen-hut bases (section 6.3.1 below).

Weigh House (building 10a)

The key to the 1926 factory plan (Fig 9) lists building 10a, situated a little to the north-west of the saltpetre refinery, as 'Weigh House'. Earlier maps indicate that the building was erected between 1863 and 1888 (compare Figs 6 and 7). It was a very small construction, no more than *c* 2m square, lying at the junction of tram lines leading from buildings used, at different times, for storing charcoal, saltpetre and sulphur (section 6.2.2 above), and also adjacent to the branch leading south-west to the Busky magazine. It was probably used, therefore, to check the weight of raw ingredients *en route* to the preparing house, and perhaps also of closed gunpowder barrels being sent to the magazine.

There is no surviving trace of the building on the ground; its site either lies beneath the concrete base of a wartime Romney hut (section 6.3.1 below) or under an adjacent raised flower bed at the front edge of what are now the gardens to 'The Charcoal Store'.

OS map evidence shows that a 'W[eighing] M[achine]' also existed at the entrance to Haverthwaite Station yard (Figs 7 and 8), but as this was situated on railway property it most probably belonged to, and was operated by, the Furness Railway Company to check the weight of gunpowder consignments received. It is not described further in this report.

6.2.10 Other Features within the Works

Blast Banks and Walls

Although incorporating mills 25/26 and, much later, the lower corning house mark IV and incorporating mills 28, 30, 32, 34 and 35 mark II (section 6.2.3 above) were all built with blast walls forming an integral part of three sides of their structure, the more normal method of blast protection at Lowwood was the erection of free-standing walls and banks between, and adjacent to, danger buildings.

The earliest recorded such free-standing structures are two walls or 'Screens' which the 1863 sale plan (Fig 6) depicts standing between the three pairs of mark I incorporating mills nos. 29/30, 31/32 and 33/34; both must have been fairly recent constructions at that time for they replace trees portrayed in the corresponding positions on the 1846 plan (Fig 4) which presumably acted as 'living' blast screens. A number of other blast walls and banks also existed at this time for a local newspaper report of an explosion at the glazing house in January 1863 refers to the presence of 'a wall twelve feet (3.66m) high and an embankment about eight feet (2.44m) high' situated between the low press house mark I and the lower corning house mark I, and another 'embankment' between the latter building and the higher corning house mark II (section 4.2 above). However, none of these is shown on the 1863 sale plan or, indeed, later maps, and their precise locations are not known. From other evidence it is known that additional blast banks were erected in the 1880s: one either side of the higher stove house in 1884, and a third south-east of the low press house mark II in 1886 (section 6.2.3 above). Strangely, the OS first edition 25-inch map (Fig 7) surveyed in 1888 does not show any of these banks, but this is probably simply because they were excluded by the OS's then rules of depiction for the map does show that additional blast walls had been erected between the remaining pairs of mark I incorporating mills, as well as in front of the charge house and south-west of expense magazine no. 1. Later maps and plans (Figs 8 and 9) attest to additional blast walls and banks shielding various buildings including the glazing house, factory magazine, cartridge-press house and cartridge-packing rooms, and possibly the high press house and higher stove house. All of these free-standing blast structures are described in detail in the entry dealing with the building which each protected (sections 6.2.3 and 6.2.4 above).

Non-Gunpowder Buildings

Cow-House (building 102b)

According to the 1863 sale plan (Fig 6), part of the former ironworks 'large' charcoal barn was for a while in use as a 'Cow House'. Whilst it is possible that this part of the barn was rented out to a local farmer for agricultural use, this seems unlikely given the building's close proximity to active parts of the gunpowder works. An alternative (and perhaps more plausible) explanation would be to see the published description as another mistake in a document which can be shown to contain a series of omissions and factual errors (section 4.2 above). If so, the alleged cow-house's position next to another part of the barn labelled as a stable suggests the published wording may actually have been in error for cart house (section 6.2.8 above). This part of the barn is shown unnumbered (apparently disused) on the 1926 factory plan (Fig 9), but will here be numbered 102b.

Wood-Boiling House (building 79)

The 1863 sale plan (Fig 6) also depicts a small structure between the saltpetre refinery and retort house which is labelled as 'Wood Boiling'. The precise function carried on in this building is unclear, but its proximity to the retort house suggests it was in some way connected with the capture or processing of the by-products of charcoal production, in particular pyroligneous acid or wood spirit. Certainly there are documentary references to the company experimenting with selling pyroligneous acid and/or acetate of lime in 1869 and again in the early 1880s (HF LW/1869/011 and LW/959/051). Acetate of lime was

produced from pyroligneous acid by adding slaked lime, and had uses as an agricultural fertiliser and later as a source of industrial acetic acid and acetone (Kelley 1986, 29-31). The building had disappeared, however, by the time the OS first edition 25-inch map was surveyed in 1888 (Fig 7), and no trace of it was found on the ground by EH during investigation.

Quarries

EH recorded a number of small quarries at various locations across the site during investigation. These are undoubtedly the result of the gunpowder company getting the stone, sand and gravel it needed for factory buildings and other constructions locally, as it was permitted to do under the 1799 lease (CRO(K) WD BGLD 2420) and subsequent renewals. However, much of the visible quarrying seems dateable to the final decades of the 19th century and later. The original lease also bestowed on the company the right to quarry construction materials on Bigland land generally, so it is possible that most of the materials needed to erect the bulk of the works in 1799 and expansion in the first part of the 19th century was sourced from quarries elsewhere on the Bigland estate, although the stone quarried during excavation of the headrace extension upstream of Stang End weir was no doubt utilised for construction purposes other than simply walling the sides of the new leat.

A small quarry measuring some 10m by 8m by 2.4m deep on the left bank of the river immediately opposite the north end of Bleaberry Holme most likely dates to *c* 1884 and represents the source for the stone used in the construction of the nearby tramway bridge abutment. It was subsequently reused as the site of a privy (building 73, section 6.2.7 above) associated with the nearby sizing, dusting and reeling house.

A second small area of stone quarrying exists immediately adjacent to the factory magazine and associated blast wall (building 60 and BW13, section 6.2.3 above) on the Stang End side of the river, and was no doubt the source of building stone for the magazine/blast wall and possibly for parts of the adjacent tramway embankment too. It most likely dates, therefore, to the period *c* 1884-6.

A series of quarry scoops cut into the rising ground north of the sawmill may have been for the extraction of sand and gravel, presumably either to make up ground levels elsewhere in the factory or to construct blast banks, *etc*. Relationships with nearby features suggest that the quarrying here was carried out over a number of decades, for at its northern end the shallowest scoop is overlain by a length of tramway embankment adjacent to the boiler house at the higher stove which the OS first edition 25-inch map (Fig 7) shows existed by 1888, whilst the large scoop nearest to the sawmill partly overlies (and must therefore post-date) the position of building 77 as mapped in 1911 (section 6.2.7 above).

Unidentified features

A low causeway, *c* 2m wide by 0.3m high, runs for *c* 40m north-west to south-east across the centre of the site, immediately north of the row of five Nissen-hut bases now used as caravan stances (Fig 142). Its function is uncertain. One possible interpretation is that it is the top of a dam structure retaining a pond, now heavily silted, to the north, but this is unlikely given that the elevation of the top of the feature is *c* 9m above OD whilst that of the

early unnamed weir to the north (section 6.1.1 above) is only 7.3m. A more likely alternative is that it is the bed of a tram line, but it does not correspond to the position of any line depicted on the historic maps showing the tramway system (Figs 7-9).

A slightly sunken platform measuring no more than 3m by 2m lies adjacent to the tram line approaching the southern end of the girder bridge over the Leven; since it is partly infilled with stone debris it probably represents the site of a small building. Although no structure is indicated at this location on any of known map of the works (Figs 4 and 6-9), the three latest maps do place the feature just beyond the north-east gable wall of the now vanished 'later' packing house (section 6.2.3 above). It may, therefore, be connected with the latter, but a more likely explanation is that it dates to after 1926 and was in some way associated with the tramway.

6.2.11 Industrial Housing

The workers' hamlet of Low Wood

The hamlet of Low Wood lies immediately south-west of Lowwood gunpowder works, close to an early crossing point of the River Leven. The settlement occupies the angle between the modern courses of the roads from Cark/Holker and Cartmel where they converge on Low Wood Bridge, although prior to 1801/3 the bridge site actually lay further to the north at Ford Island (compare Figs 2 and 3). In its present form, the hamlet lines either side of a single main street linking the two roads, which splits within the hamlet to flank a small, narrow, steeply-sloping green; the

Fig 113.
EH plan of Low Wood hamlet (based on the OS map with the permission of Ordnance Survey. © Crown copyright. All rights reserved)

majority of the houses are clustered around this green (Figs 113 and 114). But the main street is aligned on the original bridge site at Ford Island, and is therefore part of the former course of the Cark road, abandoned as a thoroughfare when the main highway was diverted to the south to meet the present stone bridge erected in 1801/3. The hamlet is now a small settlement of some 21 dwellings (not all currently occupied), with a resident population also of approximately 21. The houses are modest and mostly of mid- or late 19th-century date although a few are earlier. They are all built of stone rubble with slate roofs and are architecturally very plain and unadorned. Some around the northern fringes of the hamlet have been adapted as dwellings from buildings which were originally part of the iron- and gunpowder works, and have already featured in earlier sections detailing their industrial use.

Fig 114. Houses around the green in Low Wood hamlet, as recorded on an early postcard. (Ron Mein Collection, copyright reserved)

The hamlet was initially established for the workers of the Low Wood Iron Company, whose blast furnace stood in the original fork of the two roads (a little to the east of the early bridge). But the earliest building is in origin a farmhouse of probable 18th-century or earlier date which, apart from associated farm buildings, must have initially stood in isolation. During the period of iron production at Low Wood this farmhouse was converted into about three separate workers' dwellings, and a number of other workers' houses evidently constructed, one of them butting against the end of the farmhouse. When the blast furnace closed in 1785, the industrial buildings were abandoned (section 4.1 above) and so, probably, was the infant hamlet. However, the structures survived and the 1796-9 Bigland estate map (Fig 3), which pre-dates the opening of the gunpowder works, shows three buildings including the farmhouse, on the site of the present hamlet: two to the north and one to the south of the Cark road as it was then (Fig *). Other buildings on the plan are industrial buildings, and are not relevant therefore to the present discussion.

Although it is known that the workers' hamlet had already been established when the gunpowder works opened - dwelling houses formerly belonging to the blast furnace are referred to in the gunpowder company's lease of 1799 (section 4.2 above) - the houses which comprise the bulk of the present settlement were constructed by the latter company in the mid-19th century to house its own employees, who were also granted the right to cut peat for fuel from nearby mosses and supplied with peat houses in which to store it. Map evidence (Fig 4) shows that by 1846 the company had built the first of two simple terraces of four, two-storeyed stone houses. The second terrace was probably built soon after and by 1860 had been extended by two houses, one at either end. Low Wood House, a much larger detached residence at the north end of the hamlet also dates to before 1846, although it was much rebuilt between 1863 and 1888. It is much grander in scale and pretension than the terrace houses, and positioned so as to command a view across the works; it may have been intended for a site manager or foreman.

Since the closure of the gunpowder works, Low Wood hamlet has been maintained as an inhabited settlement and many former industrial buildings converted for use as dwellings. These include two charcoal barns, a partly rebuilt iron-ore store and two of the four cooperages, one of which served as an institute and social club for the hamlet prior to domestic conversion. Those buildings not explicitly built as dwelling houses, however, and are not described further below. Buildings described are indicated on Fig 113.

The farmhouse, nos. 2-6 Low Wood

The earliest surviving structure in Low Wood hamlet is a two-storeyed three-room plan, cross-passage farmhouse of 18th-century or earlier date which is shown, T-shaped, on the 1796-9 Bigland estate map (Fig 3). It faces roughly south and is built of rendered stone rubble with a course of water-tabling at first-floor level and a gabled slate roof. There are twin-flue end stacks and a further two-flue ridge stack positioned off-centre to the south: the position of these stacks helps to confirm the three-room and cross passage plan, as does the position of the back door which corresponds with the presumed position of the cross passage. The original front door position is obscured by a later addition to the front of the building. There is a two-storeyed rear wing, in place by the end of the 18th century, which might have been an early service wing or an addition to provide extra accommodation for workers. It is now a separate dwelling – no. 4 Low Wood. The main body of the farmhouse has been converted into three separate dwellings – nos. 2, 3 and 5 Low Wood - roughly corresponding with the original cellular divisions, and the fenestration largely dates from this remodelling. The visible front elevation, consisting of the fronts of nos. 2 and 3 Low Wood (Fig 115), is very irregular. The windows are all secondary insertions or enlargements, rectangular and lacking the heavy stone lintels that characterise the mid-19th-century terraced houses that make up most of the rest of the hamlet, and the doors give access to the individual dwellings into which the farmhouse has been subdivided. At first floor the elevation is four windows long, the second window from the left being narrower than the rest and

Fig 115.
The front elevation of nos. 2 and 3 Low Wood. (Simon Taylor, March 2004)

Fig 116.
The rear elevation of no. 5 Low Wood. (NMR DP006436)

possibly lighting a stair or landing. At ground floor the pattern is window, door, window, door, window, window. The rear elevation of no. 5 Low Wood (Fig 116), to the left of the rear wing, is also irregular and heavily rendered. There are two windows at first-floor level, three at ground-floor level and a single doorway, probably original and once opening onto the cross passage. Above and to the left of it is a narrow, mid-height stair window. To the right of the wing (Fig 117) the rear of the farmhouse is obscured at ground-floor level by a single-storeyed lean-to wing attached to no. 2 Low Wood, and there is a single rectangular window at first-floor level. The rear wing (now no. 4 Low Wood) is gabled and has a single end stack. The north and south elevations each have a central doorway, flanked by rectangular windows at ground and first floor, and the north elevation has an additional first-floor bathroom window. There is also evidence of a blocked mid-height window to the right of the door in the south elevation.

Fig 117. The north elevation of no. 4, and the rear elevation of nos. 1 and 2, Low Wood. (NMR DP006436)

By 1888 the OS first edition 25-inch map (Fig 7) shows that a gabled, west-facing, double-fronted extension, two storeys high and one room deep had been built onto the front of the right bay of the original farmhouse with which it now forms two dwellings (nos. 5 and 6 Low Wood). It is now heavily rendered and has ridge stacks at either end, although Fig 114 shows its appearance prior to modernisation. The front elevation has a central, recessed door flanked by rectangular windows at first- and second-floor level.

No. 1 Low Wood

No. 1 Low Wood (Fig 118) is a single-fronted, two-storeyed house of rendered stone rubble, with a gabled slate roof, which butts against the north end of the old farmhouse. It was probably built when the farmhouse was converted into several dwellings and appears to be shown on the 1796-9 Bigland estate map (Fig 3). It has a single end stack and the front elevation has single ground- and first-floor windows - which, like the farmhouse itself, lack large stone lintels - and a partial course of water-tabling at first-floor level. The gable end appears originally to have been blind although a single ground-floor window has been inserted and a peat house now butts against much of the rest. The rear elevation has a single first-floor window, and a single-storeyed lean-to wing has been added to the ground floor.

Fig 118. No. 1 Low Wood and peat house attached to the end of the old farmhouse. (Simon Taylor, March 2004)

Garden Cottage

The 1796-9 Bigland estate map (Fig 3) depicts a building (or buildings) in the position now occupied by Garden Cottage and an unnumbered house attached to its northern end, although the form of the present buildings (Fig 119) suggests that much is likely to be of mid- to late 19th-century date. The unnumbered house at the northern end of the range, however, appears to be considerably earlier and consists of a small, two-storeyed, single-fronted, two-roomed house built of stone rubble with a single end stack, single ground- and first-floor windows to front and rear, and a front entrance which is off-set to the right. The ground-floor windows and door all have large, roughly-dressed stone lintels, similar to those of nos. 7-10 and 12-16 Low Wood (see below), suggesting an early 19th-century rebuilding or remodelling date for the house. The front door opens directly into the single ground-floor room which has a fireplace positioned centrally against the north wall. To the left of the fireplace is a cupboard recess formed within the wall's thickness. The quarter-turn stair rises from the south corner of the room, opposite the entrance. Two stone steps against the rear wall lead up to the staircase proper, behind a door, which rises against the south-west wall towards the front of the house. By 1888, map evidence (Fig 7) shows that a block of two peat houses had been built against the north end of the house, partly wrapping around its eastern side. The house was evidently abandoned as a dwelling at a fairly early stage, probably during the second half of the 19th century following the completion of the better-appointed houses which flank the green (nos. 7-10 and 12-16 Low Wood) and served as a wash and bath house for nos. 5 and 6 Low Wood (and possibly the rest of the hamlet) for much of the 20th century.

Fig 119. The front (west) elevation of Garden Cottage. (NMR DP006437)

It is likely that the unnumbered house was originally the northernmost dwelling in a terrace of three similar houses, and something like this is shown on the portrayal of the hamlet included on the 1863 sale plan (Fig 6). By 1888, the OS first edition 25-inch map (Fig 7) shows that the two southernmost houses had been rebuilt as the one single-storeyed structure now called Garden Cottage. It is four bays long, with opposed front and rear entrances and a single brick stack: the size and form of the structure suggests that it might have been originally intended as a meeting hall or similar, rather than a dwelling house, although this is its present function.

Nos. 7-10 Low Wood

Nos. 7-10 Low Wood (Fig 120) is a terrace of four, two-storeyed, one-bay houses built in the first half of the 19th century, before 1846 (Fig 4). The houses were built in a single phase and face south-west, away from the gunpowder works. They are of stone rubble with quoined corners and a gabled slate roof. The front elevations have single windows on the ground and first floors (those

on the first floor taller than those below) with large roughly-shaped stone lintels and thin stone sills. The doorways are on the right-hand side and also have large roughly-shaped stone lintels and the doors are deeply recessed within them. Each house now has one heated and one unheated room on each floor, although this arrangement may represent a secondary subdivision of original single ground- and first-floor rooms, a ridge stack for each house carries both flues, and at the rear are shallow stair towers with single-pitched roofs, arranged in two interconnecting pairs. The entrance to each house opens directly on to a full-width, heated living-room/kitchen with a fireplace positioned centrally in the left-hand wall. To the left of the fireplace is a cupboard formed within the thickness of the wall. There is an unheated scullery beyond the living-room/kitchen with access to the stairs beneath which is a sunken storage area. Single-storeyed outshots with single-pitched roofs were added to the rear of the stair towers during the mid-20th century to provide bathrooms and an extra lean-to extension was also built at the rear of no. 7 Low Wood, beside the original stair tower.

Fig 120. The front (south-west) elevation of nos. 7-10 Low Wood. (NMR DP006432)

A little to the east of the terrace is a small gabled block (Fig 121) containing two privies that evidently served this terrace and possibly other dwellings in the hamlet. It is rectangular in plan and built of stone rubble apart from the north-west corner which incorporates firebricks from the blast furnace – reused here as quoins. The block is divided into two privies, their size suggesting a multi-seating arrangement in each, with entrances in the south-west gable and the east end of the north-west side respectively, and bricked-up rectangular raking-out openings close to the ground at the base of the south-east wall.

Fig 121. The privy block associated with nos.7-10 Low Wood. (NMR DP006433)

Nos. 12-16 Low Wood

Nos. 12-16 Low Wood (Fig 122) are a row of six terraced houses built in at least two phases in the mid-19th century, on map evidence between 1846 and 1863 (compare Figs 4 and 6). Nos. 12-15 form a single-phase development and are the earliest four houses in the row. They are very similar to nos. 7-10 Low Wood, which lie on the opposite side of the green, and were probably built soon after them. Nos. 12-15 are two storeys high and built of very roughly-coursed stone rubble with gabled slate roofs. Their front elevations are the same as those of nos. 7-10, the only difference being that the front doors are on the left, rather than the right, side of each house. Each house has one heated room per floor and a rear stair tower, making four for the terrace arranged in two pairs as they are at the rear of nos. 7-10 Low Wood, with single and very narrow windows at first-floor and small square windows on the ground floors. The main body of each house has a rectangular upper-floor window with a door below.

No. 16 Low Wood and a further house presently without a number, were added to either end of the original terrace in the mid-19th century (the former to the south end, the latter to the north end). This had probably happened by 1860 because this date appears as a *graffito* scratched on to one of the wall stones of no. 16 Low Wood (Fig 123) and both houses appear on the sale plan of 1863 (Fig 6). Both houses are built of stone rubble and have slate roofs, and clearly butt against the quoined corners of the earlier four-house terrace. The house added to the north end of the terrace (Fig 124) has remained relatively unchanged, although the back entrance has been blocked, and is very similar to its neighbours except that the front and rear windows are staggered. It also lacks a rear stair tower and has a contemporary lower north-side wing with a front door but no windows or vents: it is presumably a peat house. No. 16 Low Wood has been considerably remodelled (Fig 122). Originally its front elevation appears to have maintained the rhythm of the earlier terrace but the front doorway has been blocked and the windows considerably enlarged, the original stone lintels being replaced with timber ones with slate-tile weather-proofing. The south side had a central gable-end door or window at ground-floor level and a further first-floor window, one above the other. The upper window has been retained but the lower opening has been partially blocked and converted into a water-closet window, and a new principal doorway has also been inserted to its right and a window to its left, both with timber lintels with slate weather-proofing. Originally built without a stair tower or outshot, map evidence (Fig 6) shows that a single-storey gabled rear wing, with a single-flue end stack, had been added by 1863.

Fig 122.
The front elevation of nos. 12-16 Low Wood. (NMR DP006429)

Fig 123.
Grafitto on the wall of no. 16 Low Wood. (Simon Taylor, March 2004)

Fig 124.
The front elevation of the unnumbered house and peat house at the north end of nos. 12-16 Low Wood (Simon Taylor, March 2004)

Beside no. 16 Low Wood is a gabled stone byre or cart house (Fig 125), roughly square in plan, with the ruins of two pigsties butting against its rear wall. The byre has five surviving slit vents in its east-side elevation which also has an inserted central window. The north front has been rebuilt to accommodate double garage doors. The OS first edition 25-inch map of

Fig 125.
The stone byre or cart house associated with no. 16 Low Wood. (NMR DP006430)

1888 (Fig 7) shows a much longer building in this position, and the present one may therefore be merely a remnant of a much larger structure or range, possibly a dairy.

Low Wood House

Map evidence shows that the present Low Wood House was built between 1863 and 1888 (compare Figs 6 and 7) although a building of different plan and orientation is shown in roughly the same position on both the 1846 and 1863 plans of the hamlet/gunpowder works (Figs 4 and 6). Low Wood House (Fig 126) is the closest dwelling to the gunpowder works and is also quite different to the terrace houses further south, being both detached and much larger, and was probably built or remodelled for the site manager or foreman. It is L-shaped in plan, with a lean-to along the rear, and is probably built of stone rubble although it is now covered with thick render. The main house is two storeys high, with attic, and its long axis is aligned west to east with a front entrance on its south side. It has two rooms on each floor, heated by two stacks against the north wall. The gabled roof is of slate. A lower two-storeyed wing, two window-bays long, projects to the south and there is a shallow, single-storeyed lean-to wing with a single-pitched roof along the north side of the main house. The present front entrance to Low Wood House is situated in the left-most bay of the south wall of the main house and has a six-panel, Gothic-styled door. It opens on to an entrance corridor which abruptly turns right to run along the south side of the main house giving access to the rooms therein which are separated by a passage leading to the lean-to, and also to the south wing which contains the main staircase and has two ground-floor service rooms.

Fig 126. Low Wood House from the north-west. (NMR DP006439)

Peat houses

The 1799 lease granted gunpowder workers who lived in the hamlet the right to cut peat in nearby mosses, and each house now has a dedicated peat house. Some of these are within buildings originally constructed for different purposes, especially when they belong to dwellings established in former industrial buildings (for example the lower-floor area of the former iron-ore store opposite the modern Clocktower complex has been allocated as three peat houses, although it is possible that the middle one of these was already in use as a peat house in the 19th century (building 101b, section 6.2.7 above)), but there are a number in the hamlet which appear to be purpose-built. As well as that attached to no. 1 Low Wood (Fig 118) - which contains two stores and has opposing entrances in the east and west elevations - and that adjacent to the numberless house next to no. 12 Low Wood (Fig 124), there is a gabled stone-rubble rectangular block (Fig 127) at the south end of the green which is the peat house serving nos. 7-10 Low Wood. It is constructed like a bank barn, back to earth for half its height, and has two storeys. Each dwelling has its own individually-accessed store within the peat house, two on each floor. The ground-floor stores are accessed

by doorways in the opposing gables while the upper-floor stores are reached from upper-floor doorways in the north-east wall which can be reached because of the back-to-earth method of construction. This building is shown on the 1846 plan (Fig 4) and is probably contemporary with the terrace it serves. Another peat house was built against the north end of the house attached to Garden Cottage (Fig 119) and partly wraps around its east elevation. It is single-storeyed and divided into two stores, one reached from a doorway in the frontage to the lane, the other from a central doorway in the north gable.

Fig 127. Peat houses serving nos. 7-10 Low Wood. (Simon Taylor, March 2004)

The manager's house of Birk Dault

Birk Dault (Fig 128), also sometimes written as Birkdault, stands a little to the south of Low Wood hamlet (*eg* Fig 7), in open country with an unrestricted view to the north across the Leven valley. It is approached by two drives off the road from Haverthwaite to Holker: one the private drive which leads to the front door, the other the service drive which curves round to the back. Low Wood was a hive of building activity in the months after October 1798 as the gunpowder works was erected, and construction work included the building of Birk Dault for Daye Barker, partner in the business and works manager, and his family, to occupy; they had moved in by May 1799 (Palmer 1998, 12-13). However, references in Bigland family papers (CRO(K) WD BGLD 2420) suggest that a house already stood on the site, and this work may have involved modifications to an existing structure rather than a complete newbuild. Daye Barker died in 1835 and was succeeded by his son, Daye II, who according to the 1851 census also resided at Birk Dault. Daye II was unmarried at this time, but three other occupants are listed with him, all of them servants: Mary Rigg, aged 50, housekeeper, Agnes Campbell, aged 32, cook, and Stephen Sanders, aged 37, coachman (Cumbria Family History Society 2003, 111). In 1866, the house was occupied by Miss Elizabeth Barker (Mannex 1866, 447); her relationship to the younger Daye is unknown, but she may have been a sister or niece. In May 1871 the house was leased out, but in the late 1870s and 1880s it was back in direct company control and occupied by a succession of works managers (Richard Reynolds and later James Collinson) and their families (Tyler 2002, 132-3 and 140). By 1890, however, it was in the occupancy of Charles B Daniell, Esq (Slater 1890, 235), and by 1895 until at least 1909 Samuel Taylor, JP, lived there (Slater's and Kelly, 1895, 272; Kelly 1909, 500). In 1948 the house was bought by Dennis While, son of Augustus While.

The house is two storeys high, but two blocks are lower than the rest and appear earlier: these lie at the north-east and south-west corners (Fig 7). The block to the north-east was the original main residence, while the other is likely to have been a service block. The main residence (visible in Fig 128) was built as a one-room deep central-entry house: scars on

the front and end elevations belong to a lost 19th-century verandah depicted on both the OS first and second edition 25-inch maps (Figs 7 and 8). The front porch was added in about 1950. On stylistic grounds, the main residence was refitted internally and extended sometime during the two decades before the elder Daye Barker's death in 1835. The extensions comprised a new stair hall behind the main residence and a taller wing to its west (also both visible in Fig 128), since reduced in length. The tall wing has Tudor-style detailing which includes two-light mullioned and transomed windows, some replaced by hung sashes, with hood moulds, and chimneystacks with diagonally-set flues. The extension and refitting coincides with a period when documentary evidence (section 4.2 above) suggests the gunpowder company was prospering. A further extension was added behind the original main residence during the mid-19th century.

Fig 128. Birk Dault from the north-west. (NMR DP006423)

6.3 Phase 3. Features post-dating the Gunpowder Works

6.3.1 World War II

A number of concrete rafts survive at Lowwood which would seem to be bases for wartime Nissen and Romney huts and other structures, whilst a ditched enclosure close to the incorporating mills is also likely to be a military structure. This physical evidence ties in with reports that during the period 1939-45 the former gunpowder works was used as either a small army base (information from Mrs Stella Hartley) or a camp for Italian prisoners of war (information from Ron Mein). The EH investigation has identified ten hut bases of at least three different types, although immediate post-war aerial photography of the site suggests there were further huts, in particular in the area immediately west of the saltpetre refinery now obscured by allotment structures and/or woodland. A number of sill-beam slots on the Stang End side of the river are probably also of military origin, although the nature of the structures represented is unclear.

Nissen-hut bases

The bases of eight 16-foot (4.88m) span Nissen-hut bases may be identified with confidence: five lie in a row opposite the sawmill and incorporating mills 37/38; another two side by side close to Low Wood Bridge; whilst a singleton occupies the site of the old charge house (Fig 142). Aerial photographic evidence (NMRC 541/525 frames 3306-7) suggests a ninth base formerly existed west of the sawmill and opposite the row of five, but if so, it has either been destroyed or is now completely buried: no trace of it was found on the ground during the present investigation.

All eight of the visible examples exhibit a 0.1-0.15m wide strip around the perimeter bearing the imprint of a wall sole-plate, leaving an effective internal floor area of 10.8-11m by 4.65-4.7m. As Nissen huts were constructed in 6-foot (1.83m) bays (information from Roger

Thomas), this suggests that each base accommodated a hut six bays long. The five bases opposite the sawmill are now, or until recently have all been, used as stances for modern static caravans, and in consequence the area immediately around each has been partly obscured by raised flower beds and other forms of landscaping. But traces of concrete visible in amongst the landscaping suggest that all five bases are connected by paths; in addition, there is evidence that these connecting paths were approached from the main track in front of the huts by other paths at right angles, and it is likely that two more paths led directly to either end of the row. All five huts therefore must have been entered through doorways in their gable ends. The modern caravans now obscure much of the internal area of four of the five bases, but the easternmost base has been uplifted and shattered by tree roots and the caravan in consequence relocated on to a new area of hardstanding laid to one side, revealing the outline of the central cast-iron, pot-belly stove-hearth which originally would have heated the building (Fig 129). A similar feature can be made out at the centre of the northernmost of the pair of bases situated near Low Wood Bridge, but these lie within what is now unmanaged woodland and for the most part are heavily obscured by leaf mould and plant roots. The singleton hut base on the site of the former gunpowder green-charge house was likewise heavily obscured at the time of EH survey by undergrowth and scrap metal, although it has since been cleared in order to accommodate a circular saw and rack-bench brought to the site by the present owners.

Fig 129. The outline of the central cast-iron, pot-belly stove-hearth in the easternmost of the row of five Nissen-hut bases. (NMR DP 006443)

Romney-hut base and associated vehicle-inspection chamber

A somewhat larger concrete raft in what is now the front garden of 'The Charcoal Store' (building 8, section 6.2.2 above), would seem to be the base of a wartime Romney hut. Both long sides of the raft survive relatively intact (Fig 142) and show that the hut which formerly stood here had a width of 11m; furthermore the north-eastern raft edge preserves the tell-tale crinkle-crankle imprint of corrugated sheeting. Romney huts had a standard width of 36 feet (10.97m), and were formed of sheets of corrugated asbestos or galvanized iron attached to arched ribs (information from Roger Thomas). The exact length of the Lowwood example is unknown as both 'ends' of the raft are obscured by modern patching and/or disappear beneath raised flower beds and lawn, but aerial photographic evidence (*eg* NMRC 106G/UK 653 frame 3112) indicates that the hut extended for a considerable distance to the north-west as far as a line opposite the approximate mid-point of 'The Charcoal Store', now marked by a Leylandii hedge; it may well be that this end of the raft still survives intact beneath the modern lawn.

Romney huts typically functioned as vehicle workshops (information from Roger Thomas), and a raised vehicle-inspection chamber (Fig 142) which survives at the edge of the woodland area immediately south-west of the Lowwood example, is therefore likely to be associated with it. The chamber consists of two parallel walls, 0.82m wide by 6.29m long and 0.72m apart, each constructed out of brick and concrete to a height of *c* 0.55m and topped by a timber beam 0.15m thick; two more beams bolted at an angle against the walls' south-west ends form a ramp to enable vehicles to be driven up on to the chamber.

Other hut bases and allotments

Aerial photographic evidence from the period 1945-50 (*eg* NMRC 106G/UK 653 frame 3112 and 541/525 frames 3306-7) suggests that at least three other wartime huts formerly existed immediately south-west of the saltpetre refinery, on the edge of an area of allotments. As these allotments existed by 1945, they, too, may well have originated during the war. However, only part of one concrete base of indeterminate size plus an L-shaped scarp which may define two sides of another, is visible on the ground today (Fig 142) as the allotments are still in use and modern glasshouses and raised beds, *etc*, now obscure much of the area. It is reported that the bases were for US Army huts, one of which was resited to Haverthwaite sports ground after the War where it functioned as a cricket pavilion until at least 1962 (information from Ron Mein).

Ditched enclosure

Another feature which must represent some form of military activity is a rectangular ditched enclosure situated between incorporating mills 25/26 and 35/36 (Fig 142). The ditch is most likely for drainage, as it is only about 1.4m wide and no more than 0.3m deep. It defines an island measuring some 7.9m by 6.3m, accessed by a slight causeway approximately central to the north-west long side. The enclosure's purpose is unclear, although it may not be coincidental that it is located close to two mature ash trees whose canopies would have effectively camouflaged it from Luftwaffe reconnaissance. Similar ditched enclosures constructed around mature parkland trees at Jervaulx in North Yorkshire have been interpreted as ammunition stands (Jecock 1999, 35-6 and fig 18), although subsequent documentary research in the National Archives at Kew established that they were actually fuel dumps (information from Neil Redfern).

Sill-beam slots

A number of shallow trenches about 0.2m deep and up to 1m across are visible close to the former sites of the cartridge-packing rooms on the Stang End side of river (Fig 142), and although possibly not directly related to the activity on the main factory site are nevertheless most likely to be sill-beam slots dating to the Second World War. Two separate structures are represented: one consists of two parallel slots *c* 4.4m – 5m long and a similar distance apart; the other of two interconnecting slots arranged as a 'T'. The nature and function of both is unclear.

6.3.2 Structures of the 1950s and later

Around 1950, Augustus While who had purchased the site of the gunpowder works when it closed in 1935 (section 4.2 above), embarked on a scheme to use the available water power to generate hydro-electricity for use in Low Wood hamlet and for sale to the National Grid. The scheme involved re-routing the lower part of the headrace in an elevated concrete launder to supply a new hydro-electricity station constructed close to where the headrace originally discharged into the Leven. The elevated launder was supported and retained by a massive embankment constructed of slag and rubble, which buried many previously extant gunpowder structures immediately north of the saltpetre refinery. The power station housed two Francis-type turbines each capable of generating 218bhp (163.5kW), purchased from Gilkes & Co of Kendal in 1952/3 (information from S Bianchi); the western, concrete, wall of

the power station is visible in Fig 12. It is reported that While also attempted to meet the hamlet's demand for electricity using a small Armfield turbine abandoned on site when the gunpowder works closed (information from Oliver Barrett), and which seems to have been relocated to the basement of incorporating mill 36 in the 1960s, probably replacing an earlier unit. If so, both smaller turbines were inadequate to the task; the disused Armfield unit still survives (incorporating mills 27-38, section 6.2.3 above).

In the mid 1960s the level of the Eel Dams weir was raised to create an enlarged head of water in the headrace; this necessitated raising and strengthening the sides of the headrace which in many places were relined in concrete at this time.

A small concrete structure opposite the row of five Nissen-hut bases houses a toilet, and is presumably a waste-disposal facility connected with the static caravans which now occupy the site.

A number of small holes and quarries across the site, particularly into some of the blast banks, are modern disturbances probably for building material.

7. DISCUSSION AND CONCLUSIONS

Chapter 4 of this report reviewed the documentary evidence for the industrial development of the Lowwood site, while chapter 6 presented a detailed account of individual buildings and features based on historical sources as well as investigative field survey of the surviving visible archaeological and architectural evidence. The present chapter is intended as a commentary on all this evidence, highlighting uncertainties in the data, contradictions between datasets and problem areas requiring further research; it is also a first attempt to set that information into its wider local and national historical context. In addition, section 7.3.2 contains a brief assessment of the likely state of preservation of some remains now buried, and of the threats which the site as a whole presently faces.

7.1 The Pre-Gunpowder Landscape

7.1.1 Burnbarrow Forge (Fig 130)

Previous discussion of the documentary evidence for the Burnbarrow bloomery forge (above, page 12) flagged the probability that the place names Burnbarrow and Low Wood are one and the same, and that the early 17th-century Burnbarrow bloomery forge therefore stood on, or in close proximity to, the site of the subsequent 18th-century Lowwood blast furnace/ forge complex. Evidence for the precise location and layout of Burnbarrow forge is hard to come by, but a number of clues are provided by a previously overlooked map referred to in this report as 'the 1796-9 Bigland estate map', and reproduced here as Fig 3.

First, the observation has been made (above, pages 17 and 45) that the unnamed but apparently disused weir which the map shows upstream of the old Low Wood Bridge, is unlikely to be connected with the 18th-century ironworks and is more likely to have originated as part of Burnbarrow forge. Secondly, although the map does not portray a leat system connected with the weir, a pronounced curve in the south-west boundary of the field immediately to the south (labelled 'cc' on the map) is a curious detail highly suggestive of the course of that boundary being dictated by a pre-existing feature on the ground - possibly either a dam for a hammer pond, or perhaps more plausibly the rear edge of that pond. Thirdly, it has also been suggested (above, page 46) that the building at the south-west edge of the adjacent field (labelled 'wc' on the map), is the later, 18th-century Lowwood forge; if so, particularly given its situation in relation to the possible hammer pond, it must be a distinct possibility that it marks the site of the earlier Burnbarrow forge too.

Apart from the presence of large quantities of smithing slag observed by EH in the river bank opposite and upstream of the suggested forge site, however, no field evidence survives to substantiate this layout of Burnbarrow conjectured from map evidence. The later, 18th-century, Lowwood forge building appears to have been demolished when the gunpowder works was established, and if a hammer pond still existed as an earthwork to its rear as suggested above, this was progressively infilled after 1799 when a series of incorporating mills was constructed in the area. Neither is there any visible trace of the course of a leat connecting the possible pond with the unnamed, early weir, but again this area was subject to substantial

alteration during the site's later transformation into a gunpowder works. The ideas outlined here will therefore only be confirmed or refined by additional fieldwork, most probably necessitating excavation. The only upstanding feature from this period appears to be the southern end of the unnamed weir (above, page 45). This weir has what would appear to be an unconventional profile in that its downstream face is vertical while its upstream face is battered. The significance of this observation, however, is unclear.

7.1.2 Lowwood Ironworks (Fig 131)

The Lowwood ironworks was one of a group of eight blast furnaces established in Furness and adjacent parts of Lancashire and Westmorland in the first half of the 18th century. All eight furnaces were charcoal-fired, building on a tradition of ironworking in the area which can be traced back to medieval times. The remains of the four best preserved blast furnaces (Backbarrow, Duddon, Newland and Nibthwaite) were examined in detail by EH as part of a recent study of Furness ironworking based on the surviving field evidence (Bowden 2000). Lowwood was visited as part of this study and the survival of an iron-ore store and charcoal barn noted, but in-depth recording and investigation was not carried out. This omission has now been remedied by the present study, which although directed principally at the later gunpowder works, has for the first time recorded in detail what survives of the earlier ironworking landscape too. The interpretation of those remains has been aided by a previously unknown map (the Bigland estate map) which, it has been argued, depicts the layout of the ironworks in its final form at some point between 1796 and 1799, and by a deposit of papers (CRO(K) WD BGLD 2420) which, although not studied in detail, reveal that contrary to previous views, the Lowwood blast furnace and its associated buildings were not dismantled when the ironworks was shut down in 1785, but merely allowed to fall into disrepair (above, pages 13-14 and 17).

The map evidence indicates that the ironworks comprised a total of six buildings arranged either side of the Cartmel road running south-east from the end of old Low Wood Bridge. Although none of these buildings is named on the map, the function of at least half (the blast furnace plus a 'large' charcoal barn and iron-ore store which supplied it) can be deduced from a combination of their relative positions, other documentary evidence and the fact that parts of all three structures still survive. It has been suggested above (pages 45-6) that the remaining three buildings should be identified as the forge referred to in documents, a second, (small) charcoal barn whose existence is also implied, and a stable and/or cart house.

The impression gained is that, in terms of general works layout, Lowwood conforms to the pattern of Furness blast furnace sites identified by Bowden: a furnace complex situated to one side of a valley bottom with storage buildings positioned on the valley side immediately above. This arrangement was adopted for the very simple reason that the weight and quantity of iron ore, charcoal and (if necessary) limestone flux required to maintain a prolonged blast (which could last for months if not years), meant that special attention had to be paid to how those raw materials arrived on site and were subsequently transported between the storage areas and the furnace stack (Bowden 2000, 48-50). Thus ore stores and charcoal barns were normally sited along the contours of a slope behind the furnace, to enable raw materials to be offloaded at ground level into the rear of the buildings, brought out at ground level at the front, and barrowed straight into the top of the furnace stack. Just such an arrangement

utilising the fall of the ground to minimise movements of heavy raw materials uphill is admirably demonstrated at Lowwood (see particularly Fig 13 in this report).

The general size and design of individual buildings at Lowwood is also very much akin to that found elsewhere in Furness. The 'large' charcoal barn is now so heavily altered internally and externally that direct comparisons cannot usefully be made. The iron-ore store is far better preserved, however, particularly at ground-floor level. Whereas it has previously been stated that it belongs to the class of stores with open interiors, the present investigation has demonstrated (above, pages 50-2) that, to the contrary, it should be placed in the class with divided interiors evidenced at Leighton, Newland and the northern store at Backbarrow (Bowden 2000, 59-60). The layout of the blast furnace complex also follows the pattern familiar from other Furness sites, with a central furnace stack abutted by bridge/charging, blowing and casting houses (above, pages 48-50). However, the map evidence indicates that at Lowwood these three elements were combined with other ranges to create a T-shaped complex, evidently much larger than neighbouring furnace complexes in Furness. Although the positions of the charging, blowing and casting houses can all reasonably be deduced, the function of the additional ranges is presently unknown.

It has previously been stated that the blast furnace at Lowwood was dismantled when the ironworks closed in 1785 (*eg* Bowden 2000, 8). However, the present investigation has uncovered evidence (above, pages 13-14) to suggest that rather than being demolished, the various components of the furnace complex were merely allowed to fall into disrepair before being converted into a saltpetre refinery when the lease was reassigned to the gunpowder company in 1799. The degree of rebuilding undertaken by the new lessees is unclear, but it has here been suggested (above, pages 48-50) that large parts of ironworks fabric may have survived until 1849 when the present saltpetre refinery was erected to much the same footprint as the earlier building. Indeed, the bridge house was not finally demolished until 1928, and even then incompletely for parts of two of its ground-floor walls still survive as features within a modern garden. Furthermore, the present investigation has demonstrated that two single-storey wings or sheds at the south-west end of the refinery seem to incorporate elements of the original casting house, and has suggested (above, page 77) that the irregular spacing of the roof trusses at the northern end of the more easterly of the two wings may in some way be associated with this area being the site of the furnace stack – perhaps, for example, indicating that the walls and roof were extended over the site of the stack whenever the latter was demolished. The northern end wall of the same wing also contains three blocked arches, now only visible on the outer face of that wall when viewed from inside the adjoining clock tower erected in 1849 (above, page 78 and Fig 38). Since these arches do not seem to have any structural role as part of the tower, it is possible that they, too, are a remnant of the early ironworks, although if so, they are of unknown function.

Lowwood belongs to that subset of Furness ironworks which operated a forge alongside the blast furnace. Bowden (2000, 64) has pointed out that blast furnaces needed a regular, reliable and abundant supply of water to power their bellows, but that forges also relied on water to operate bellows and tilt hammers, thereby creating the potential for conflict since a furnace needed its bellows to be working constantly if the blast was to be maintained over

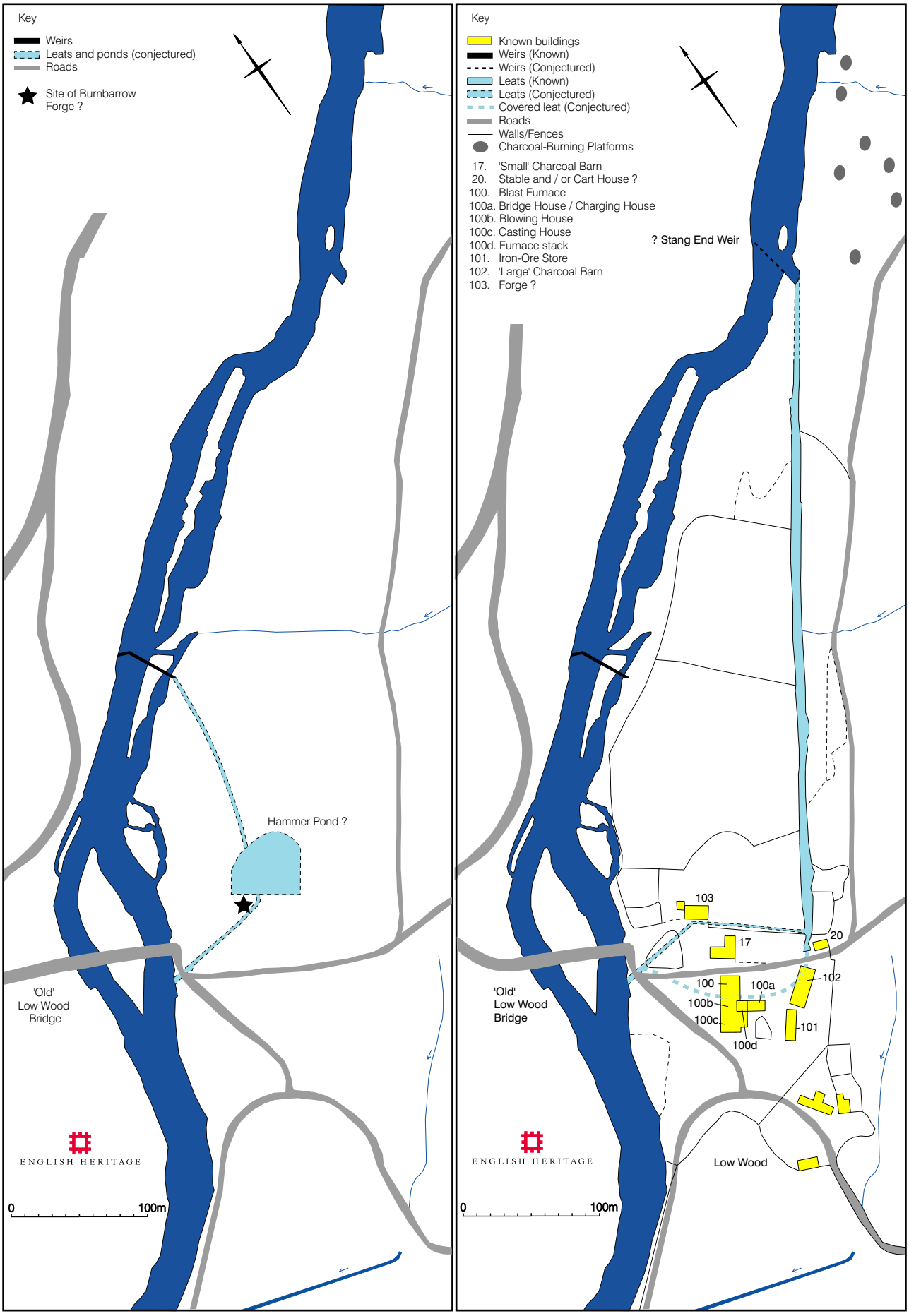


Fig 130 (left). EH conjectural plan of Burnbarrow Forge, c 1603-22
Fig 131 (right) EH plan of the ironworks and its immediate landscape setting, c 1748-98

a prolonged period: if a forge relied on the same source of waterpower as the furnace, it risked disrupting the supply to the latter. For this reason and on the basis of a brief documentary reference quoted secondhand by Alfred Fell, Bowden has suggested that the Lowwood forge had its own weir and leat system separate from that supplying the blast furnace. Interpretation of the depiction of weirs and leats on the 1796-9 Bigland estate map is not straightforward, but it has been argued above (pages 17-18) on the basis of earlier and later documentary references, that contrary to Bowden's suggestion, both buildings were powered from a single weir situated at Stang End. The weir is not portrayed on the 1796-9 map, but it has been argued that this was because it was then ruinous. Its position can be deduced, however, because the map shows a long headrace approaching the blast furnace which leaves the river on the outside of a westward bend. EH found no definite physical traces for a weir in this position during investigation, but field evidence in the form of a kink in the course of the headrace - which was extended after 1799 - points to the same general siting for it (above, page 57). Much or all of the weir has been destroyed by the river, but it is possible that slight traces are still preserved in the river bed or buried in either bank, in which case they may be revealed by future erosion (above, pages 46-7). A second weir is depicted on the map further downstream, but this was most probably already disused when the ironworks was in use, since another reference indicates that the forge was powered from the main headrace, and the gunpowder company's lease of 1799 only mentions a single weir and headrace. The present study has therefore suggested that the forge lay on a subsidiary branch of the headrace which came off at right angles back towards the river, and has identified building 103 as the most likely candidate for it. An alternative, but less likely, position for the forge is that it was located in the northern range of the blast furnace complex. Whatever the truth, the proximity of the L-shaped building (building 17) to either location suggests that it can be identified as the second 'small' charcoal barn whose existence is implied in documents, and which presumably stored charcoal for the forge.

7.2 The Gunpowder Works

Prior to 1863 the founders of the Lowwood Gunpowder Works mostly traded under the name of the Low Wood Company, with the topographic element written as two words mirroring the modern form of the place name. However, to limit confusion the following discussion will mostly refer to both the factory and early partnership as Lowwood, which was the name the company adopted in 1863 and is the form which most commentators use to refer to both the company and site today (above, pages 1-4).

7.2.1 The Early Years of the Low Wood Gunpowder Company, *c* 1798-1827 (Fig 132)

None of the four men making up the original partnership had any direct experience of gunpowder manufacture prior to setting up the Lowwood works. This much is clear from letters written between them (Palmer 1998, 1-3). Nevertheless, it seems likely that, as suggested by Palmer (1998, 30), the initial driving force behind the enterprise was Christopher Wilson, partner in the Kendal bank of Maude, Wilson and Crewdson. Wilson's Kendal connections meant he would have moved in the same social circles as John Wakefield I, co-founder of the first gunpowder works in southern Lakeland which was established *c* 1768 outside the village of Sedgwick (Jecock and Dunn 2002, 8 and 37). He would therefore have

known that there was potentially money to be made from gunpowder: Wakefield had by this time acquired full control of the Sedgwick company, diversified into banking (Marshall 1975, 221), and built a large mansion, Sedgwick House, out of his profits (Jecock and Dunn 2002, 12).

In addition to vision, however, it is likely that as a banker, what Wilson brought to the partnership was financial knowledge and access to capital (although all four partners seem to have put £3000 into the business as start-up capital (Palmer 1998, 5)). Of the other partners, Fayrer was a sea captain with experience of trading out of Liverpool to West Africa, which seems to have been one of the target markets for the new enterprise, forming one leg of the 'triangular' slave trade until that was abolished in British vessels in 1807. He may have been recruited by Wilson, therefore, largely because of his knowledge and contacts in that area, although he also seemingly had at least one friend in the gunpowder business elsewhere (see below). Barker was a man of practical business experience, having previously been active in cotton manufacture, and reportedly at some point owner-manager of the local Backbarrow cotton mills. Even though there is absolutely no evidence that he had had previous experience in manufacturing gunpowder, he seems always to have been earmarked by his fellow partners as the one who would manage and oversee the new enterprise on a day-to-day basis (Palmer 1998, 21-9). This is shown by the fact that the partnership financed the construction of a large house for him and his family to occupy at Birk Dault on the southern edge of Low Wood hamlet, which was finished by May 1799 several months before the factory was ready to start production (above, pages 15 and 195). The priority which Barker (who was also the active on-site partner charged with the responsibility of supervising the construction and fitting-out of the new factory) apparently gave to the completion of Birk Dault, seems to have generated a degree of friction between him and Wilson, who was anxious to commence powder production as soon as possible in order to begin to see a return on his investment (Palmer 1998, 13). In contrast, King was a local landowner and man of wealth, and seems to have had no particular skills which would have recommended him to Wilson other than his money and, possibly, standing in society; according to a letter which Wilson wrote in September 1801, his main role within the company was to be debt collection although he also managed the general accounts (Palmer 1998, 23).

Palmer (1998, 57) has calculated that between 1798 and 1807 the four partners invested a total of £6,291 in constructing and equipping their new factory (her quoted total of £6,323 seems an arithmetical error). By far the biggest proportion of this amount - £4,272 or 68 per cent - was spent on building costs, with the balance split almost equally between the purchase of millstones and other items with which to fit out the factory. Although she does not present the detailed annual balance sheets used to arrive at these totals, by far the majority of this expenditure must have been incurred between October 1798, when construction work started, and August 1799 when the factory produced its first powder. Tyler (2002, 99) has stated that the building account included the costs of 'construction of the [?incorporating] mills, weirs, charcoal house, office and store', but his list clearly omits Birk Dault and the Roudsea store magazine which were both completed by the company in 1799. In fact, EH has found evidence or has speculated that the range and number of buildings which either had to be erected from scratch or converted out of existing structures prior to the company commencing

production, included a saltpetre refinery, corning house, stove house, and packing house. Although the ICI historian adds both a press house and glazing house to the initial building stock (Imperial Chemical Industries 1929, 340), there must be some doubt as to whether this was actually so (the question is explored in more detail below). One or two extra incorporating mills, a new boiler for the stove house, and five charcoal retorts and a fire engine (plus sheds to house them) had all been added to the infrastructure account before 1803 (above, pages 15-16).

Since the earliest plan of the gunpowder works so far discovered is dated 1846 (Fig 4), it is impossible to be sure of the precise factory layout at this early time. However, Fig 132 is an attempt to show what buildings were present and how they may have been arranged in 1827. Inevitably this assumes that if a building is documented as in existence by 1827, it occupied the same position as in 1846.

As already noted, Tyler states that the early building accounts included the cost of building 'weirs', whereas in the present report it is argued (section 4.2) that in 1799 the partners constructed only a single weir, Eel Dams, as a replacement for the iron company's Stang End weir which appears to have been ruinous anyway. The new weir stood some 200m upstream of the old, which meant that the headrace had to be extended, mostly through solid rock, to meet it; the junction of the new work with the old is apparent on the ground as a distinct kink in the course of the headrace (above, page 57). The reason for extending the headrace rather than simply repairing the existing weir must have been in order to increase the head of water to generate sufficient power to drive all the different machines required for gunpowder manufacture. It has also been argued in this report (above, page 56) that the final (covered) section of the headrace before it reached the blast furnace was retained by the gunpowder company as a bypass channel, while what had been the subsidiary branch to the forge was adapted to power the initial incorporating mill or mills. However, as the gunpowder company chose to convert the blast furnace into their saltpetre refinery, it is possible that the bypass channel was also used to supply water to that building. Saltpetre was refined by both washing and boiling, and the process therefore required copious amounts of water; it would seem logical that water was drawn or pumped up from the leat which passed beneath the building. It has been suggested above (page 50) that the old blowing-house wheel was probably a hindrance in the conversion of the blast furnace to its new function of saltpetre refinery, and that it was most probably removed straightaway. However, an alternative is that it was retained and used to raise water. Another (but not necessarily mutually exclusive) scenario is that the wheel could have initially powered the edge-runner mill(s) used in the grinding up or preparation of saltpetre, sulphur and charcoal (the three raw ingredients of gunpowder), and that what is shown on Fig 132 as the 'earliest' preparing house (building 81) was not in fact constructed until some time later. But it should be emphasised that this is all pure conjecture, and that there is no evidence, documentary or physical, to support either suggestion.

Tyler also states that the initial building account included the cost of construction of an office. This is presumably the same building as the counting house named on the 1846 plan, situated at the north end of the former iron-ore store. The building seems to have been sited so as to control pedestrian access to the site through the narrow passage between it

and the southern end of the adjacent 'large' charcoal barn; certainly later on, this passage was gated (above, pages 171-3).

All previous studies of the gunpowder works have accepted the statement made by the ICI historian (Imperial Chemical Industries 1929, 340) that the factory commenced production with 'six [incorporating] mills'. However, in this new study EH has presented evidence which contradicts that assertion (above, page 16), and has made a case that production started with a single mill or at most two mills arranged as a pair, with a third added before 1826, most probably in 1803. This is all the more likely when it is realised that the company employed only seven men in 1800 (Palmer 1998, 33). Two of the three early mills must have been what were later known as the stone mills (incorporating mills 25/26) since the superstructure was of a totally different design to any of the other twelve which existed by 1846, but it is unclear where the third mill was located. For the sake of Fig 132 it has been assumed that this third mill was building 27. Admittedly the identification is again conjectural, but building 27 does seem the most likely candidate since it lies closest to what in 1846 was the site of the watch house, and would therefore have allowed for ease of supervision by the mill-keepers.

EH has also highlighted in this report the fact that the original fourteen incorporating mills were of two designs (above, pages 82-98). Palmer (1998, 1-2) has pointed out that the partners seem initially to have been in ignorance of the designs of machinery and buildings needed for their new factory, and resorted to surreptitious visits to at least one other gunpowder works in the vicinity (at Thelwall, in Cheshire) to see for themselves how powder incorporation was done. The bulk of their information, however, seems to have come to them quite openly from a contact, James Stevens at the Faversham gunpowder factory in Kent, with whom Fayrer had dealings, and it has been speculated above (page 88) that the design of the two stone mills was based on Faversham prototypes. If a third mill was operational by 1803 as here suggested, it was presumably of the same design as the others erected between 1828 and 1846 since there is no evidence that it was demolished at that time. Assuming that it was of the same design as the later mills, the change of form could be explained as the result of experience gained in the early years of manufacture, or simply as an in-house solution to the requirement to get a third mill operational very quickly to take advantage of a market opportunity. The second design of incorporating mill bears close similarity to the mills later erected at Elterwater, but since that factory did not build its first mill until 1824-5, the influences, if there were any, presumably went from Lowwood to Elterwater rather than vice versa (although see Jecock *et al* 2003, 98 and 101-2 for an alternative possibility).

The ICI historian also states that Lowwood possessed a press house as early as 1799. However, EH has found no independent evidence in support of this statement, and indeed no evidence for the existence of a press of any kind prior to 1861 (above, page 24). No separate press house is indicated on the 1846 plan, and given that the ICI historian can be shown to be in error in the matter of the number of incorporating mills at the works in 1799, considerable doubt must attach to this part of his evidence too. It is possible that the reason why no press house is named on the 1846 plan is that the process was located in one or both of the corning houses. The plan identifies two corning houses, both consisting of two compartments arranged one either side of a central wheel-pit, and it is theoretically possible

that one compartment housed a press rather than corning machinery; if so, proximity to a source of power would suggest that the press was hydraulically rather than manually operated. However, it is presently unclear whether either of Lowwood's local competitors before 1827, the Old Sedgwick and Elterwater gunpowder factories, pressed their powder prior to corning. Indeed, the Elterwater factory reportedly did not acquire a press until 1829, almost four years after it produced its first powder (Jecock *et al* 2003, 16 and 64), and there is absolutely no evidence that the Wakefield family, who owned the Old Sedgwick factory, pressed their powder at all before they relocated operations to Gatebeck in 1852 (Jecock and Dunn 2002, 24 and 41). Pressing had the effect of increasing the keeping quality of gunpowder, but actually reduced its explosive strength (Curtis 1996, 253-4), and in the earlier 19th century may not have been considered an essential part of the manufacturing process for blasting powders. Indeed, in 1801 the company made the switch from buying in charcoal produced in traditional clamps to producing their own by the cylinder or retort method, ostensibly because the latter was proven to result in a stronger powder (above, page16).

We can perhaps have more confidence in the ICI historian's statement that Lowwood possessed a corning house in 1799. Certainly Lowwood was corning its powder by 1823 for in July of that year the corning house exploded, killing two men working inside; the scene of this accident can be identified as what was later known as the higher corning house (above, page 105). A second corning house existed by 1846 as evidenced by the 1846 plan. Its date of construction is not known, but the desire for it may have originated as a reaction to the 1823 explosion to ensure continuity of production in the event of another accident, or simply in order to increase production levels. For the purposes of phasing, it is here assumed that it was added after 1827, and it is therefore omitted from Fig 132. Corning machines at this date are likely have been of the old shaking-frame type. The newer, safer design of corning machine which used rollers or 'crackers' to break up the press cake, was invented around 1816 by Sir William Congreve the younger, who had succeeded his father as comptroller of the Royal Laboratory at Greenwich (Cocroft 2000, 63). However, the old frame-type corning machines most probably persisted at the civil gunpowder factories until much later in the century.

As with pressing, there is currently no firm evidence that Lowwood glazed its powder during the first six decades of the 19th century: certainly no glazing house is named on the 1846 plan, and the earliest documentary evidence for glazing is *c* 1861 when a dedicated reel and glaze house was constructed at the works. However, it is possible that, like pressing, glazing was carried on at an earlier date in the corning house(s); certainly in January 1863 one half of the higher corning house was dedicated to glazing for the barrels blew up and the explosion quickly communicated to other buildings (above, pages 23-5).

Lowwood certainly stoved (dried) its powder as early as 1799, as is indicated by reference to the proposed site of a stove house in the company's initial lease (above, page 15). As with corning, a second stove house existed by 1846, but for phasing purposes it is again assumed here that this second stove was not built until sometime after 1827. Although the company had teething problems with their design of boiler, they did use the more modern and safer method of drying the powder in houses heated by steam pipes rather than in gloom stoves which persisted at Elterwater, for example, until 1881 (Jecock *et al* 2003, 70-1). The site of this

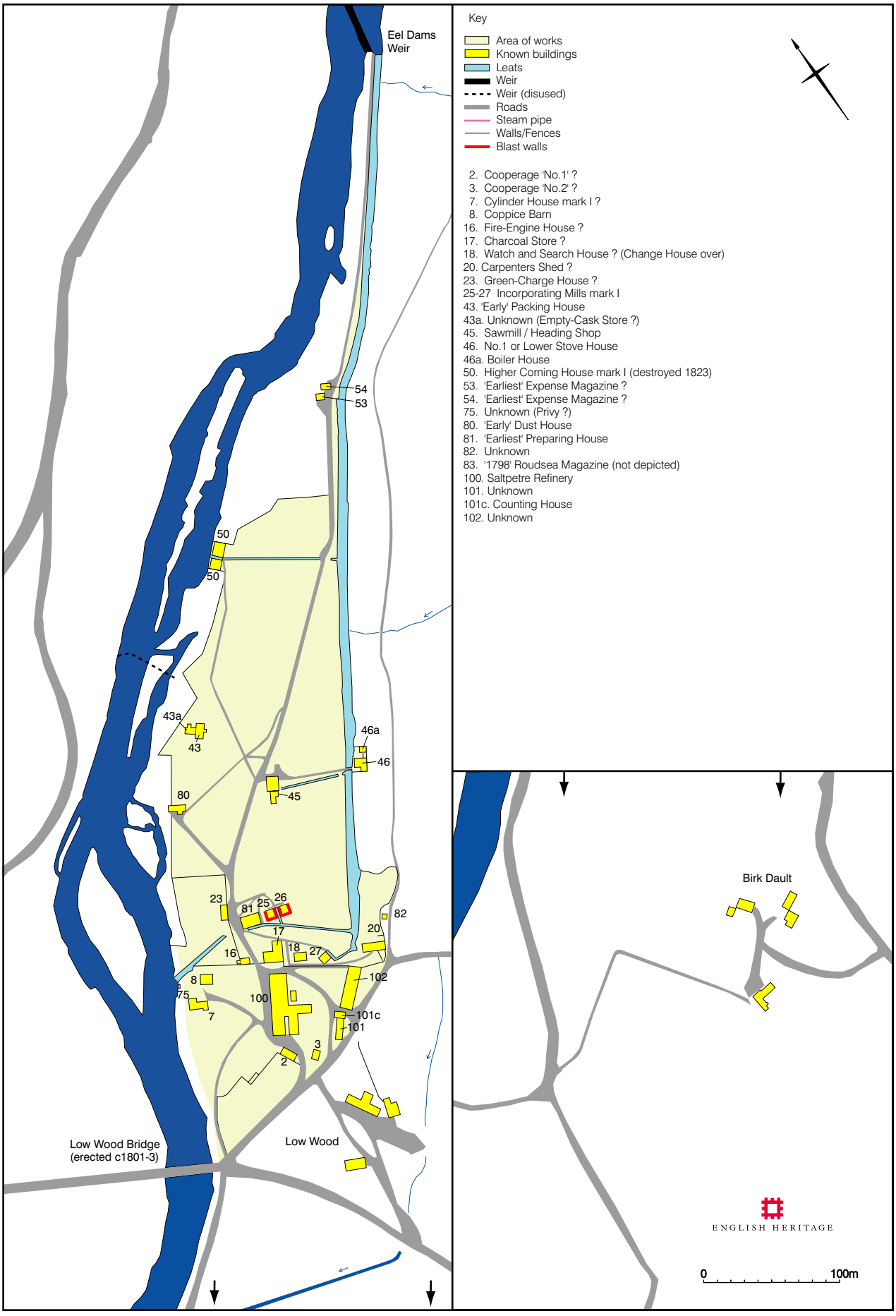


Fig 132. EH phase diagram of the gunpowder works, c 1799-1827

first stove can be identified with some confidence as what later became known as the lower stove. It lay adjacent to the works headrace on the east side of the works, well away from other buildings. There were probably two reasons for this: one, safety, in order to prevent sparks from the boiler chimney being blown across the factory by the prevailing westerly wind and causing explosions; the other, was simply proximity to a supply of water for the boiler.

Whilst there is no firm evidence that Lowwood dusted its powder when it commenced production, a dust house is shown on the 1846 plan and can almost certainly be assumed to have occupied the same site since 1799. Similarly, right from day one there must have been somewhere where the finished powder could be packed into barrels, and for present purposes it seems logical to assume that this was the building identified as the packing house on the 1846 plan ('early' packing house, building 43). The finished powder was stored in the magazine at Roudsea ready for despatch to customers, mostly by sea.

The company also brought in most of its supplies by sea, probably through the local ports of Greenodd and Ulverston (above, page 15). Although the previous ironworks had operated its own small quay, Bigland Dock, on the Leven just downstream of the works (Bowden 2000, 36-7), there is currently no evidence that the gunpowder company availed itself of this facility, probably because the dock was only usable by vessels of limited draught. Until *c* 1803 Low Wood Bridge was sited at Ford Island rather than its present position someway downstream of the works (above, page 14). This meant that for the first four years or so that gunpowder was produced at Lowwood, the public highway ran much closer to the incorporating mills and other danger buildings than afterwards. Whilst it is tempting to think that the reason for re-routing the road was to remove the public highway to a safer position, it may simply have been because the existing timber bridge was badly decayed and in need of replacement (Stockdale 1872, 367-8).

Birk Dault was extended and refitted internally for Daye Barker sometime before 1835 (above, pages 195-6), presumably reflecting the fact that the company was making good profits. Indeed in 1825 the other surviving partner in the business, Christopher Wilson, bought a new estate, Rigmaden Park at Mansergh, north of Kirkby Lonsdale, and erected a sizeable mansion for himself designed by the local architect George Webster (Taylor 2004, 119). That development, too, may well have been partly financed out of the dividends which he accrued from his Lowwood investment.

7.2.2 Early expansion, *c* 1828-48 (Fig 133)

The renewal by Barker and Wilson of their lease of the Lowwood site in December 1827 over twenty years before the original lease expired is strong evidence that, as suggested above, the company was by now making good money, and that the partners were confident of continued profitability. It would seem sound commercial sense that they should also seek to secure their tenure of the site if they were about to invest large sums of money in new infrastructure. For this reason, it has been argued above (page 18) that the bulk of the expansion which the 1846 plan shows had occurred by the middle of the century, should be dated to 1828 and later. Hard evidence that the company was making major investments in extra plant at just this time with a view to raising levels of production comes from the report

of the completion of a second store magazine at Roudsea in September 1836 with the capacity to house 1500 barrels of gunpowder - one and a half times the capacity of the existing magazine (above, pages 18 and 142-6). Indeed, confirmation that the years of the second quarter of the 19th century were a time of great prosperity for the Lowwood company is provided in a letter written by George Jackson in 1871. Jackson was a clerk at the works for almost 21½ years until probably the early 1860s: census records state that he was aged 47 in 1851 (Cumbria Family History Society 2003, 109), although he seems to have retired or left the company's employ prior to early 1863. He states that the overall profit to the company in his time was £176,290 (HF LW/1871/006) – equal to at least £18,000,000 in modern values (information from Dr Paul Barnwell). Expressed another way, by the 1840s the company was making the equivalent of £1 million a year profit at today's prices.

The 1846 plan shows that the company had increased its stock of incorporating mills from three to fourteen since 1828, although there is no evidence that this happened all at once. The increase was probably phased in over at least two stages: six of the new mills share the same take-off from the headrace suggesting they were erected as a single development (above, page 83). The eleven new incorporating mills all differed from the earliest two examples (mills 26/26) - but probably not the third dating from 1803 - in being no more than simple wooden sheds over gearing basements shielded from each other by free-standing blast walls, rather than having blast walls as an integral part of the mill structure as in that earliest pair. The origin of this second design of incorporating mill is presently obscure (section 7.2.1 above), but it does suggest that over a quarter-century of manufacturing experience had demonstrated to the company that the original design was over-engineered or unnecessary in some way - perhaps simply too expensive and time-consuming to construct for any advantages it gave.

The 1846 plan also shows that the company had erected a second corning house and stove by 1846. Since it also depicts a road leading straight from the higher corning house to the higher stove (there is no evidence that Lowwood glazed its powder at this time (section 7.2.1 above)), and since the lower corning house is shown without a comparable direct road connection with the upper stove, it suggests that each of the stoves serviced the output of just one of the corning houses. The plan also indicates that the company now manufactured its own barrels: three buildings are portrayed at the southern edge of the works which are known all to have been cooperages in 1863 (above, pages 165-7), whereas in 1799 barrels were reportedly bought in from an independent supplier in Kendal (Tyler 2002, 98). However, this switch to in-house production of barrels and the provision of additional coopering capacity were undoubtedly both phased in over time and should not all be dated to after 1828.

The plan also indicates that building 18 - which the present investigation has shown started life half its present size and which in 1863 is named as the wood warehouse, probably representing a coppice barn storing raw material for charcoal manufacture (above, pages 63-5) - had reached its final size before 1846. Obviously, if the company was expanding output, it also needed to increase its stock of, and capability to process, raw materials. This would necessarily have included saltpetre and sulphur, although the impact is not so readily apparent in the cartographic and physical evidence. Increasing production levels meant that the company would also have had to take on more workers, making it likely that

new houses which the plan shows had been built in Low Wood hamlet since 1796-9 probably date to after 1828, too. The company inherited a small number of worker's houses from the preceding iron company as part of the original 1799 lease, but the plan shows that the company had also constructed a terrace of four, very simple two-storeyed, one-bay houses before 1846 (above, pages 187-192).

Low Wood House in Low Wood hamlet was first erected between 1799 and 1846, although it was rebuilt or substantially altered between 1863 and 1888 (above, page 194). At least in its later form it was a higher class of dwelling than other buildings in the hamlet, and this plus its elevated position close to the works suggests it may have been constructed specifically as a managers or foreman's house, sited with a view of the works so that the incumbent could readily monitor his charge for signs of problems even when at home. The manager's house, Lindeth, constructed at the nearby Blackbeck gunpowder works around the turn of the 20th century had an analogous situation in respect of that factory (Dunn *et al* 2005, 127). As both Daye Barker I and II are known to have lived at Birk Dault, it may have been built for the second Daye's younger brother, John – although by 1851 the latter was resident at Broughton Lodge, possibly because Low Wood House was too small for someone who was now married with five children (Cumbria Family History Society 1991, 83). It may thereafter have been occupied by a succession of works managers, in particular William Sealy (manager between ?1859 and 1863) who was brought in to help John run the works following Daye II's death, and his immediate successor, John Dodgson (1863-9); indeed, it may have been for Dodgson that the house was rebuilt and enlarged after 1863. Later managers were resident elsewhere, however: Richard Reynolds (manager 1869-79) lived initially in Levenside, and then at Birk Dault, while James Collinson, his deputy and later his successor, lived first in Rose Cottage and then replaced his boss at Birk Dault (Tyler 2002, 132-3 and 144). After 1869, therefore, Low Wood House may have been downgraded into a residence for the works foreman or clerk.

7.2.3 Celebration and Consolidation, *c* 1849-58 (Fig 134)

By 1849 the Lowwood company had evidently been producing gunpowder very successfully and profitably for 50 years. The factory had just completed a *c* 20-year period of expansion and improvement (section 7.2.2 above), and the partners seem to have decided to mark the occasion of the company's fiftieth anniversary by rebuilding the saltpetre refinery (above, pages 20 and 67-78), although this may have been necessitated anyway by a change in the refining process followed. A good deal of the existing complex – which probably retained much of the structure of the ironworks blast furnace from which it was converted – was demolished and replaced, although respecting much the same footprint. The newbuild element consisted of an L-shaped, two-storey, structure consisting of a main rectangular block housing a row of six furnaces and boiling pans, and a smaller north-eastern wing probably intended as warehousing. Two sheds at the south-west end of the refinery plus the old ironworks bridge house were retained, the former presumably because they were already well-suited to the crystallising and washing parts of the refining process; the use to which the bridge house was put is not recorded, but since it was no longer connected to the other parts of the refinery it was probably only used for general storage or as extra accommodation

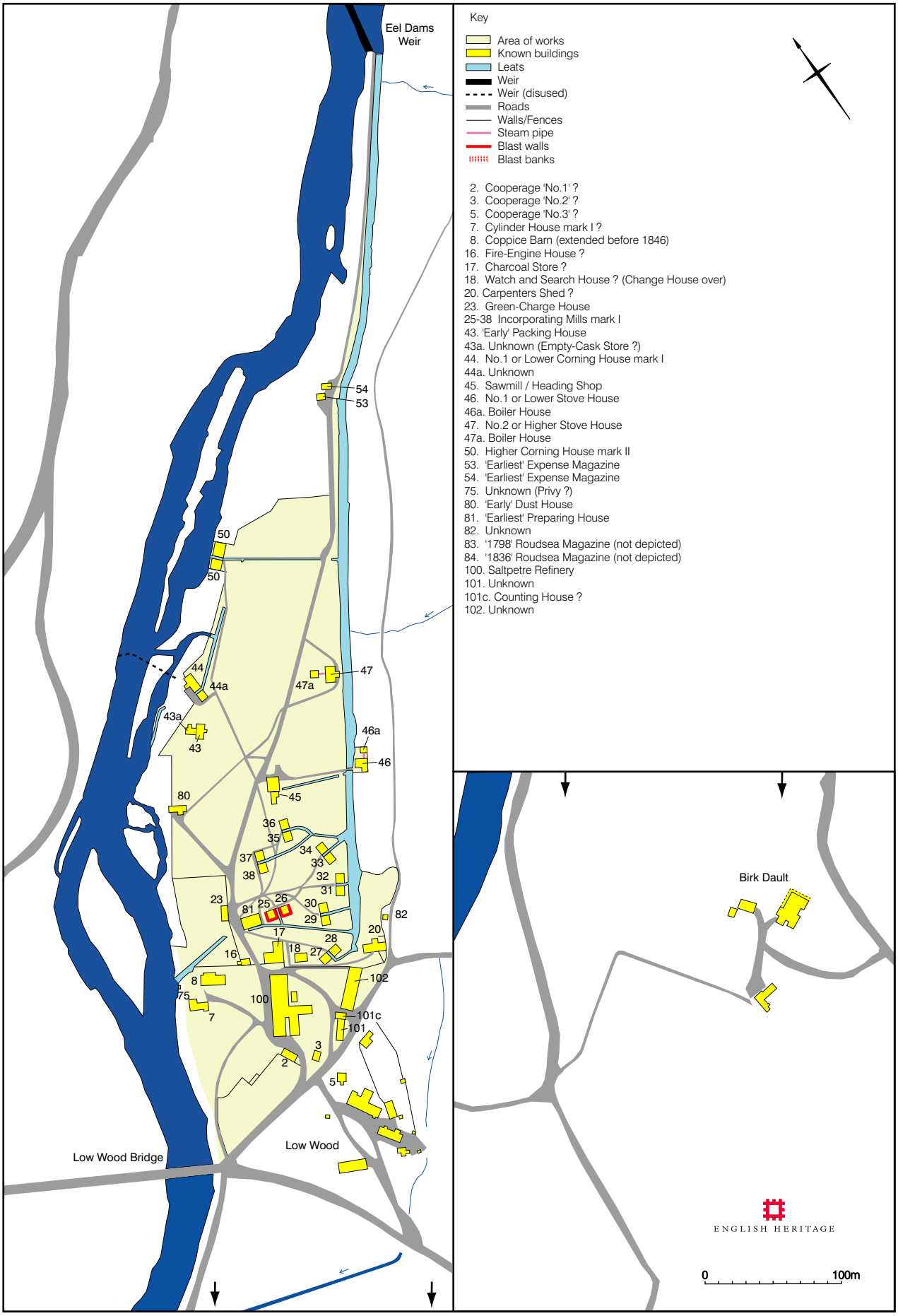


Fig 133. EH phase diagram of the gunpowder works, c 1828-48

for the workforce. However, the partners did erect a new, 40-foot high clock tower as part of the refinery. Since the single clock face on the tower faces north-west across the river, it would not have been visible from many places within the factory and must be interpreted therefore primarily as an eyecatcher to the outside world and as a statement of the company's presence, status and profitability. It may even have been in conscious emulation of the form of the old furnace stack which stood on almost the same site, and which presumably had been a much-noticed local landmark in its day. The clock mechanism appears to pre-date 1849, but it is unclear where it was sited prior to installation in the tower at Lowwood (Crocker and Crocker 1989). It was probably at this time that the southern end of the former ironworks 'large' charcoal barn became the saltpetre store (building 102a and above, pages 65-6) and was connected to the refinery by an elevated tramway (as shown on the 1863 sale plan, Fig 6), for the boiling pans in the refinery were designed to be accessed at first-floor level.

With the exception of the refinery, building development at the factory seems to have been limited for the next ten years or so, certainly when compared against what had gone before, indicating perhaps that the factory was undergoing a period of consolidation. But there is evidence that the company did construct a second terrace of four worker's houses in Low Wood hamlet (now nos. 12-15 – above, pages 192-4) in this phase: the fact that an additional house (no. 16) was built on to the southern end of the terrace in or before 1860, shows that the original terrace was erected no later than the 1850s. The company also increased its office space in the northern and southern ends of the former iron-ore store at some point between 1846 and 1863 (above, pages 171-3); one or both of these developments may well date to this phase.

However, competition was increasing at this time as, nationally, more gunpowder manufacturers entered what they saw as a very lucrative market. Indeed, within Cumbria alone, the Old Sedgwick factory closed and moved to new, modern facilities at Gatebeck in 1852 (Jecock and Dunn 2002, 9), while fresh concerns were established at New Sedgwick in 1857 and at Blackbeck, only 2km from Lowwood, in 1861-2 (Dunn *et al* 2003, 19; 2005, 19). Anecdotedly, it is reported (HF LW/1871/006) that through existing powder works expanding capacity and new manufacturers entering the market, the supply of blackpowder more than doubled in Britain during the three years of the Crimean War alone (1854-6). The consequential severe competition resulted in diminished profits for all. But profits there still were, as is shown by renewed investment recorded for Lowwood after 1859 (section 7.2.4 below).

7.2.4 Military Adventure: renewed investment and setback, *c* 1859-63 (Fig 135)

Daye Barker II died in 1859, and in this report it has been argued that it was now rather than as early as the 1830s - as seems to be implied by Tyler - that his brother John decided to engage the services of one William Sealy, sometime manager of the Tonbridge Gunpowder Works in Kent, to help run Lowwood (above, pages 18 and 22). An additional reason for the appointment may well have been John Barker's desire to diversify away from the production of primarily blasting powders into other areas of the market, in particular sporting and government (military) powders in which Sealy seems to have had experience. The move into more specialist powders was presumably John's answer to the emerging problems of oversupply of ordinary powders alluded to previously (section 7.2.3 above).

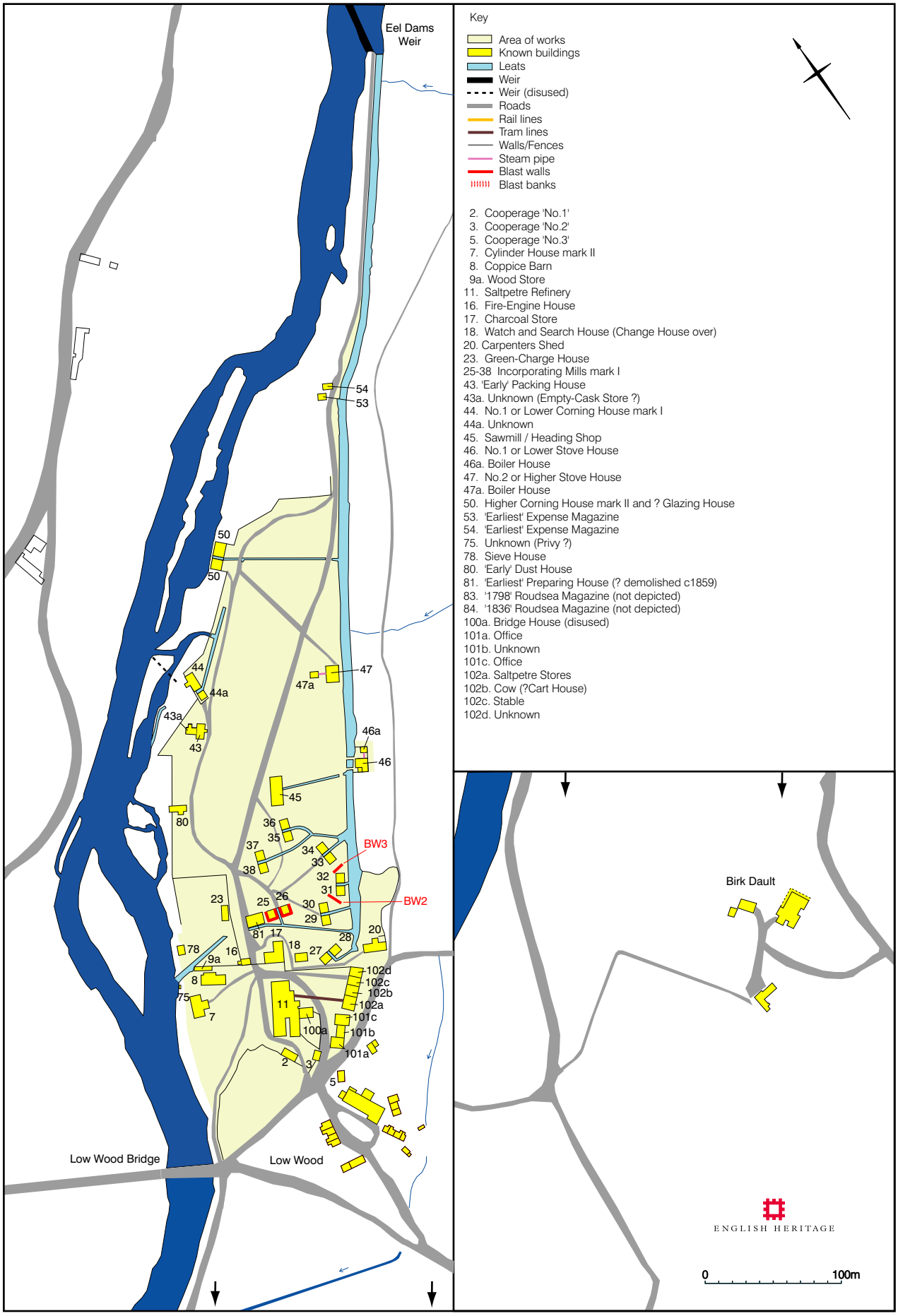


Fig 134. EH phase diagram of the gunpowder works, c 1849-58

One consequence of such a move into specialist, higher quality, powders would have been the need to provide facilities at the works for pressing and reeling and glazing – always assuming of course that they did not exist already (section 7.2.1 above). The available evidence fits this pattern very well, for the earliest report of the existence of a press at Lowwood is dated June 1861 when the company ordered a hydraulic press from the London firm of Hopkinson & Cope, whilst the first mention of reeling and glazing does not pre-date 1861 (above, pages 22-4). Powders for the military also had to be proved (that is, demonstrated as being of the required strength and quality) before they were accepted by the Board of Ordnance, and this involved the construction of one if not two proofing ranges in the open ground at the centre of the factory. Although there is slight evidence for the existence of a proofing range on a different part of the Lowwood factory before 1846, this is very much circumstantial and inconclusive, and it seems likely that the provision of the new ranges was intimately linked with the move to begin production of military-grade powder. The first government order was won in 1862 (above, pages 24-6 and 152-4).

However, the company was making fresh investment in other areas of plant, too, much of it apparently aimed at raising production levels in addition to enabling diversification into specialist products: in 1859 new corning machinery was purchased, the lower stove provided with a new boiler which required altering the boiler house, and a second preparing house constructed, whilst in 1861 the company leased extra land bordering the river to provide space and power for additional buildings, including – seemingly for the first time – a press house and reel and glaze house. The erection of the former building necessitated the resiting of the existing, 'early', dust house (building 80), while that of the latter building the resiting of the existing, 'earliest', expense magazines (buildings 53 and 54), since as danger buildings, legally, none of these could be within 40 yards of each other (above, pages 22-4, 98-103, 121-2, and 136-7). In 1862 a fire in one of the preparing houses - probably the new, timber, preparing house no. 2 (above, pages 24 and 79-81) – spread to the two nearest incorporating mills whose wooden elements were also destroyed. It has been argued in this report (above, pages 82-9) that the burned-out mills were the earliest, stone, mills, nos. 25/26, and that the fire was the occasion for the substitution of ring gearing in place of the original drive mechanism which took power off the waterwheel axle.

Another development which had its roots in this period was the company's use of the railways to transport goods. The opening in 1858 of Cark station on the new line between Ulverston and Carnforth meant that Lowwood now had a link into the national rail network only 9km from its door. Carriage by rail was initially more expensive than sea, but was quicker and less dependent on tides and weather; the Ulverston to Carnforth line also entailed the construction of a viaduct across the Leven estuary which rapidly proved itself a nuisance to the passage of ships to and from the ports and moorings which Lowwood had traditionally used upriver (above, pages 178-80). The existing magazines at Roudsea were too far away and in the wrong direction for Cark station, so in order to make best use of the new method of transport the company constructed a new store magazine closer to the factory. The chosen site in Busky field stood in the lee of a natural rock outcrop, and was only 500m from the factory; the magazine was operational by 1861 (above, pages 22 and 146-7).

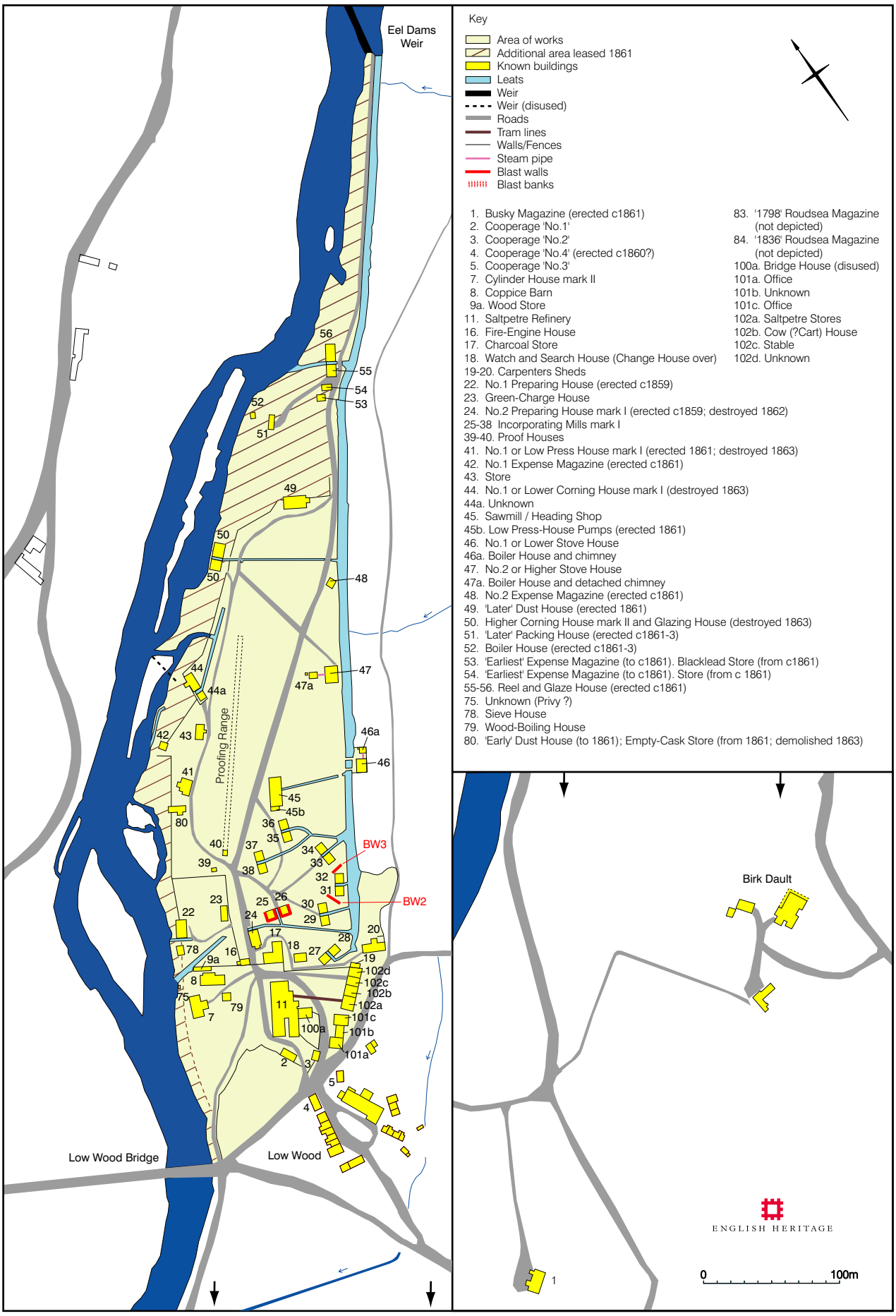


Fig 135. EH phase diagram of the gunpowder works, c 1859-63

In 1863 we have the first record that the company was obtaining a small extra income from sale of the waste from saltpetre refining (called refuse salt) as an agricultural fertiliser (above, page 69), but it had probably received such income in previous years, too. The presence of a wood-boiling house (building 79) on the 1863 sale plan is unexplained, but may indicate that the company was trying to boost revenues further by starting to sell the by-products of charcoal manufacture (above, pages 185-6).

Everything changed in the first half of 1863, however, following an explosion which occurred in late January at the higher corning house, part of which was also by this time in use as a second glazing house (section 7.2.5 below).

7.2.5 Retrenchment: the early years of the Lowwood Gunpowder Company Ltd, 1863-8 (Fig 136)

The 1863 explosion originated in the combined higher corning/glazing house, and communicated to the lower corning and press houses, killing six men (above, page 24-5). It was attributed to the incautious cleaning of the glazing barrels by one of the labourers (appendix 1 below), but if the powder adhering to the barrels and being processed in the other buildings which exploded was 'Tower Proof' (that is military grade, containing 75 per cent saltpetre), it would have been a more powerful powder than Lowwood was used to handling, and may help to explain why the initial explosion communicated to buildings at least 75m distant.

The consequences of the accident radiated far beyond the immediate scene of death and destruction, however. Production levels of all powders seem to have been severely affected, and eventually the company was unable to meet its contract for supplying powder to the government. John Barker was so disturbed by events, that by June he had signed control of the works over to a new company trading as the Lowwood Gunpowder Company Ltd to distinguish it from the earlier partnership, and no longer took an active part in everyday decisions. Sealy seems to have borne much of the blame for the accident, and either left or was dismissed; he moved on to be manager at the Kames gunpowder works in Scotland (Tyler 2002, 121). His replacement was John Dodgson.

The new management team set about rebuilding the factory and making it safer to operate. They very soon took the decision to separate spatially the processes of corning and glazing: the combined glazing/corning house which had been the source of the accident was rebuilt as a dedicated glazing house, while a replacement (high) corning house was constructed at the very top end of the works. The destroyed lower corning house was rebuilt on its old site, but the replacement lower press house was moved to a new position some 24m further away from the corning house, and a second (high) press house was constructed also towards the vacant top end of the works well away from other buildings (above, pages 25-6 and 100-21). The new company also rapidly abandoned the idea of producing military-grade powder: certainly by 1869 both proofing ranges seem to have been disused (above, pages 153-4 and 184), with the associated proof houses converted into ancillary buildings for the internal tramway system introduced that year.

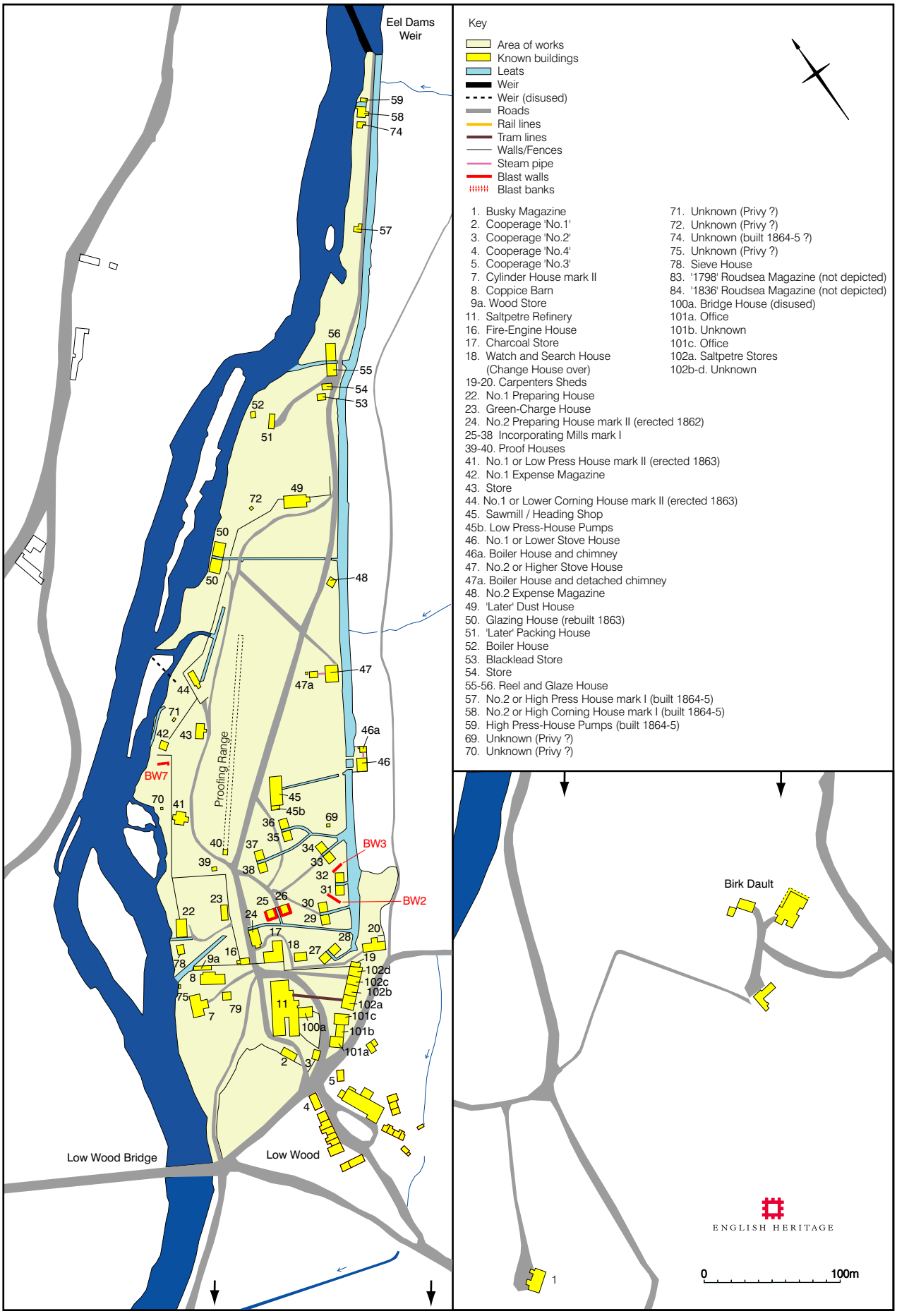


Fig 136. EH phase diagram of the gunpowder works, c 1863-8

Thus by 1865 when the last of these new buildings was completed, Lowwood finally had two press houses, two corning houses and two glazing houses, all well spaced across the factory to minimise the risk of secondary explosions communicating between them. It is unclear how much the high press and corning houses were in active use at this time. The principal logic behind their construction appears to have been that they were in reserve so that production would not be interrupted in case of further accidents at the main houses, but they were also to provide cover for periods when the main houses were temporarily out of action through maintenance and repair. The costs of rebuilding the works in this way were considerable, however: the machinery alone for the new high corning house cost over £922. Although the overall sum for construction and new plant is not known, it would easily have run into many thousands of pounds. This expenditure coincided with a marked decline in the price of gunpowder which reportedly followed the ending of the American Civil War in 1865 (HF LW/1871/006). Taken together, the two events no doubt severely affected the profitability of the new company in the first few years of trading. Three years later there was another fatal explosion at the works (section 7.2.6 below).

7.2.6 Stagnation: the later years of the Lowwood Gunpowder Company Ltd 1869-82 (Fig 137)

On 28 November 1868, the lower corning house exploded killing the five men working inside (above, page 28). John Dodgson left his position as manager, to be replaced by Richard Reynolds, a civil engineer with no previous experience of the gunpowder trade. The reasoning behind his appointment may well have been for him to cast a professional engineer's eye over the machinery and processes employed at the factory to see if and how they might be improved from a safety viewpoint. Certainly, the directors of the company were anxious to have a new design of corning machine which needed fewer men to operate it, and which would thus reduce the potential for death and injury in the future (it might not have escaped their thoughts that it should be cheaper to operate too). In the event, after touring around other factories and seeing the types of corning machines in use elsewhere, Reynolds agreed a new design with the firm of Hastie & Co, who seem to have been Lowwood's preferred supplier for corning machinery from 1863. This new machine required the oversight of only two men. The new company was either careless or unlucky in its general operating procedures, however, for it suffered further losses both to its reputation and balance sheet in March 1871, when the high corning house exploded, destroying the building and much of the expensive machinery within; a further four men died (above, pages 28-9).

After reconstruction of the lower corning house in 1869, the next big task undertaken by Reynolds was construction of a system of tram lines linking the various buildings and parts of the factory. The trigger for the scheme appears to have been the opening of the Furness Railway Company's branch line along the Leven valley, which passed close to the factory on the opposite side of the river. However, contrary to Tyler (2002, 131), it has been argued in this report that the tram system was initially confined purely to the area of the factory, and had no direct connection to Haverthwaite Station on the branch line until 1883/4 (above, pages 28, 30 and 181-4). Lowwood's local competitors in the gunpowder business such as the Elterwater and New Sedgwick Companies were also putting down internal tramway

systems at around the same time (Tyler 2002, 176; Dunn *et al* 2003, 115) - in Elterwater's case perhaps as early as 1867 - suggesting that the scheme may simply have been part of a more general fashion, or a desire to emulate improvements taking place elsewhere. The industrial use of narrow-gauge railways had been revolutionised in 1862 by John Ramsbottom, Chief Mechanical Engineer at the Crewe works of the London & North Western Railway, who had constructed an 18-inch (457.2mm) gauge light railway to transport goods and products around the works; the narrowness of the gauge meant that the railway could run inside buildings and also that curves of tighter radius were possible than on standard-gauge lines (www.royalgunpowdermills.com/railway_system.htm). However, the relevance of his innovation to the civil gunpowder industry is unclear, as the gauge adopted by the various Cumbrian works was at least twice that used by Ramsbottom, and the lines normally passed by on the outside of buildings, not through them. Furthermore, the systems were always worked by men or horses, since the risk of sparks from steam locomotives igniting gunpowder as it was being carried in canvas-covered tubs into and out of buildings was considered too high.

As a civil engineer, Reynolds was no doubt abreast of developments in technology, and it may, therefore, have been at his suggestion that the company invested in its first water turbine in 1872, although there is no information as to where it was placed or what it was intended to power (above, pages 29 and 61). Compared to other gunpowder manufacturers in Cumbria, Lowwood occupied neither the van nor rearguard in recognising the advantages of turbine technology over waterwheels: at New Sedgwick, for example, turbines provided power for the preparing house, corning house and cooperage right from start of production in 1857 (Dunn *et al* 2003, 26), whereas Elterwater did not acquire its first turbine until 1878 at the earliest (Jecock *et al* 2003, 33). Lowwood's tardiness in the field may have been for two reasons: cost - even when buildings such as the corning houses exploded, the waterwheels were probably relatively little damaged since they sat quite low down within their pits – and the fact that the factory was so well sited and supplied with water that it could generate sufficient power anyway.

The passing of the Explosives Act in 1875 had a major effect on the gunpowder industry, and Lowwood was no exception. The Act brought in a new licensing system for all places where explosives were manufactured, administered for the first time not at local level by justices of the peace but by central Government acting through the newly formed Explosives Inspectorate at the Home Office. Every existing works was required to apply for a continuing certificate, to obtain which a large-scale plan of the factory had to be submitted to the Inspectorate showing the position and function of each building. This was so that the Inspectorate could check the spacing between all buildings, and ensure it conformed to legal requirements and/or best practice. Provision of blast protection generally halved the permitted distance (Patterson 1986, 12-13; Cocroft 2000, 99-100). Lowwood was duly issued with continuing certificate no. 23 in April 1876 (Explosives Inspectorate 1887, 3). The fact that after this date, evidence of many more blast banks and walls at Lowwood starts to appear must be largely down to safety improvements demanded by the Inspectorate.

Another consequence of the Act was that it was now illegal to produce blasting cartridges except on licensed premises. Prior to 1875, many miners and quarrymen made their own cartridges; after 1875, these had to be purchased from licensed manufacturers. As with

other gunpowder companies, Lowwood sought to take advantage of this new market for its product, but seems to have been slow off the mark. Although it experimented with the small-scale production of compressed pellets using a wooden hand press in 1875, it thereafter encountered problems with patents taken out by competitors to protect the design of compressed cartridges and the machinery required to manufacture them on an industrial scale, and did not succeed in producing its own such cartridges before 1882 (above, page 29).

Demand for gunpowder, and the production of it, reached a peak in Britain in the 1870s but declined thereafter as newer, improved forms of explosive began to challenge its position as the explosive of choice (Cocroft 2000, 67). The effect of rising demand in the first part of the decade can perhaps be seen at Lowwood in a proposal Reynolds put forward in 1872 to increase production levels further by resiting the sawmill and constructing four extra incorporating mills in its place (above, page 29). It was probably a good thing, however, that nothing was done (the directors considered the scheme too costly), as by the end of the decade the company was experiencing keen competition and finding trading conditions extremely difficult (HF LW/959/051 and 055), and Reynolds' successor as works manager from 1879, James Collinson, was touring the north of England in 1881 trying to drum up orders (Tyler 2002, 145-6; HF LW/959/064-109 *passim*).

The company appear to have examined several ways of boosting income in this period. In 1869, for example, it apparently looked at the possibility of capturing pyroligneous acid (a by-product of cylinder-charcoal manufacture) and selling it, or its distillates, commercially (HF LW/1869/011). The matter was taken no further at the time, but in 1880-1 it experimented again with manufacturing acetate of lime (calcium acetate), produced by adding slaked lime to the pyroligneous acid (Kelley 1986, 31). At this period, acetate of lime was widely used as the raw material for both acetic acid and acetone. There are no further references to the trade, however, and it appears to have been a short-lived venture which may already have been abandoned by the time in 1882 the company directors decided to sell the business to one of their local competitors, W H Wakefield, who operated Gatebeck and the Basingill outstation (section 7.2.7 below).

7.2.7 New Direction: the early years of the Wakefield takeover, 1882-8 (Fig 138)

At a local level the takeover by the Wakefield company, which took effect on 20 November 1882 (above, page 29), ties in well with a national trend towards rationalisation and consolidation of the industry in the years after 1850, for by 1918 the number of gunpowder works in Britain had been reduced by about a quarter, and many of the others brought under unified control (Cocroft 2000, 67). The Wakefield takeover of Lowwood seems very quickly to have provided much-needed new direction for a factory which, despite the evident advantages of its situation in terms of space, availability of waterpower and access to transport links, had struggled since 1863. In its near twenty years of existence the previous company had suffered a succession of major accidents which had proved very costly not only in terms of lives lost, but also damage done to the factory's infrastructure and balance sheet (sections 7.2.5 and 7.2.6 above). The spate of structural changes apparent when control of the works passed to Wakefield's, however, plus a subsequently much-improved

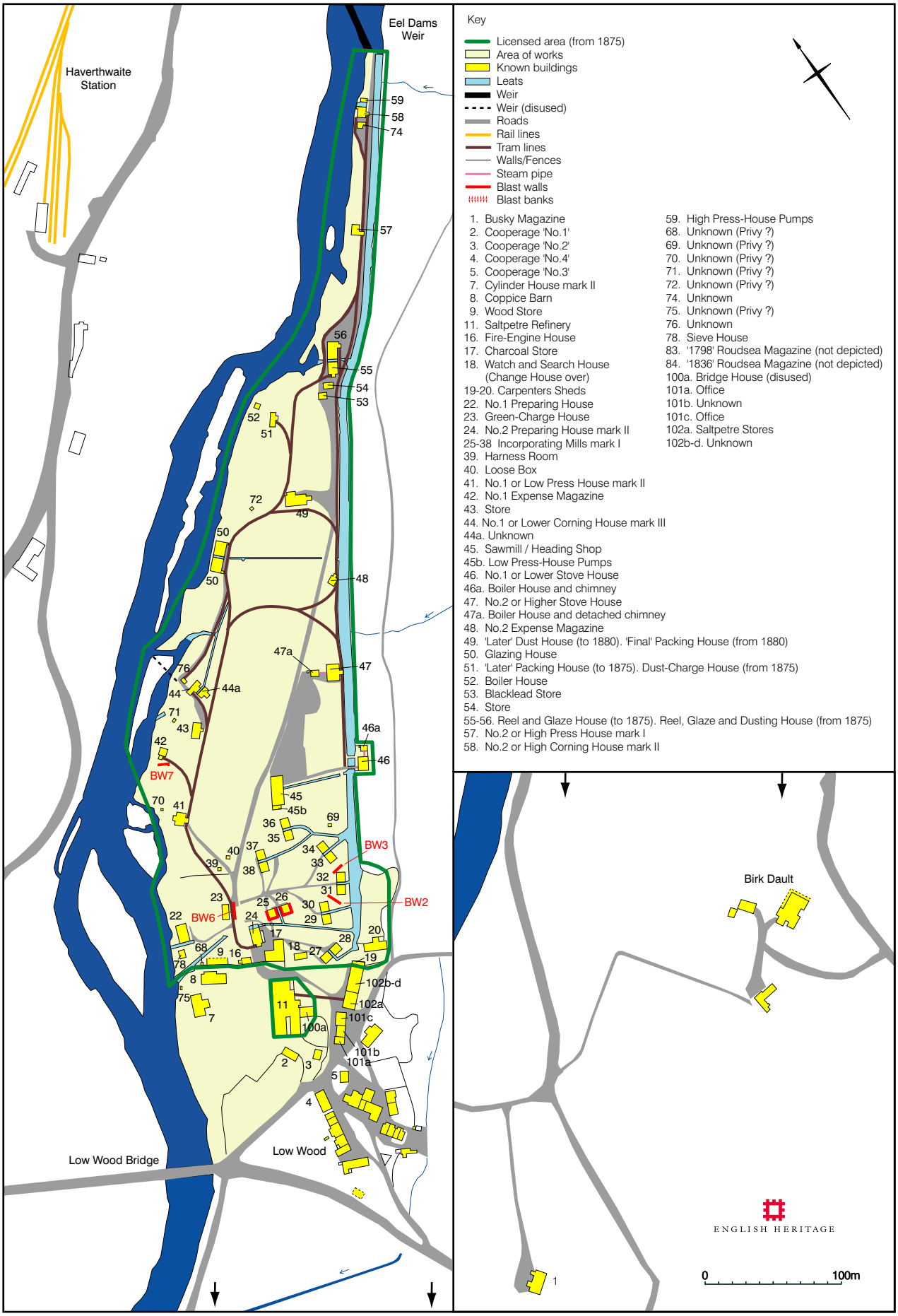


Fig 137. EH phase diagram of the gunpowder works, c 1869-82

safety record, suggests that many of the problems which the old company had encountered and which had been at the root of its relative unprofitability, were largely failures of management.

Some of the changes which the Wakefield company brought in at Lowwood immediately after 1882 were of its own devising. These included unspecified improvements in the way in which the factory and production were organised, necessitating application to HM Explosives Inspectorate as early as April 1883 for authority either to alter physically, or change the function of, a number of buildings (above, pages 29-30). Major alterations and extensions to the layout of the internal tramway system were also in hand at this time. These involved most notably the construction in 1883-4 of links from the factory out to the Busky magazine and to Haverthwaite Station on the other side of the river, eliminating the need for those journeys to be undertaken by horses and carts, but a whole series of minor re-routings were also made to the track layout around the factory, presumably to render the transfer of powder between process buildings more efficient (above, pages 30 and 181-3).

It is less clear, however, how much other documented changes were planned or were forced on the company by the Explosives Inspectorate. For example, new blast banks were erected shielding the higher stove in 1884 (above, page 131), whilst between *c* 1886 and 1888, the new owners radically overhauled the way in which blasting cartridges were manufactured at Lowwood. It has been argued in this report (pages 103 and 149) that for a few years after 1882 cartridges were formed at the high press house and packed at the 'final' packing house – a system which Wakefield's inherited from the old company. However *c* 1886 a purpose-built cartridge-press house was constructed on the site of one of the two existing preparing houses, and an hydraulic accumulator installed to operate it (above, pages 148-51). This seemingly required the installation of a buried pipeline bringing in pressurised water from Bigland Tarn. Why pressurised water was needed is unclear since the accumulator was raised by pumps anyway, but EH has suggested that it was to reduce the amount of work the pumps needed to do to attain the operating pressures required by the accumulator; the pumps were eventually driven from the sawmill. Meanwhile, the company's ownership of land at Stang End - purchased by the previous management in 1863 (above, page 26), and which was now connected to the main part of the works following the construction of the tram line to Haverthwaite Station in 1883-4 - was developed for other stages of the cartridge-manufacturing process, namely wrapping the cartridges in waxed paper and placing them into boxes (above, pages 151-2). The gunpowder trade normally employed women to perform these jobs (perhaps because they were deemed non-manual tasks), but this necessitated the company investing in a second set of changing facilities too (above, pages 156-7). The company also erected an additional magazine especially to store the boxed cartridges, and a blast bank protecting the lower press house; both the latter developments were definitely at the behest of HM Explosives Inspectorate (above, pages 147-8 and 149).

EH has also suggested above (page 92) that Lowwood may have been amongst those factories which gained dispensation from the Explosives Inspectorate in 1886 to incorporate larger charges of up to 36.32kg at a time, on the proviso that it installed blast walls at least 0.61m thick between the mills. At present the evidence is entirely circumstantial, but certainly additional blast walls were erected between each pair of mills at some point between 1863

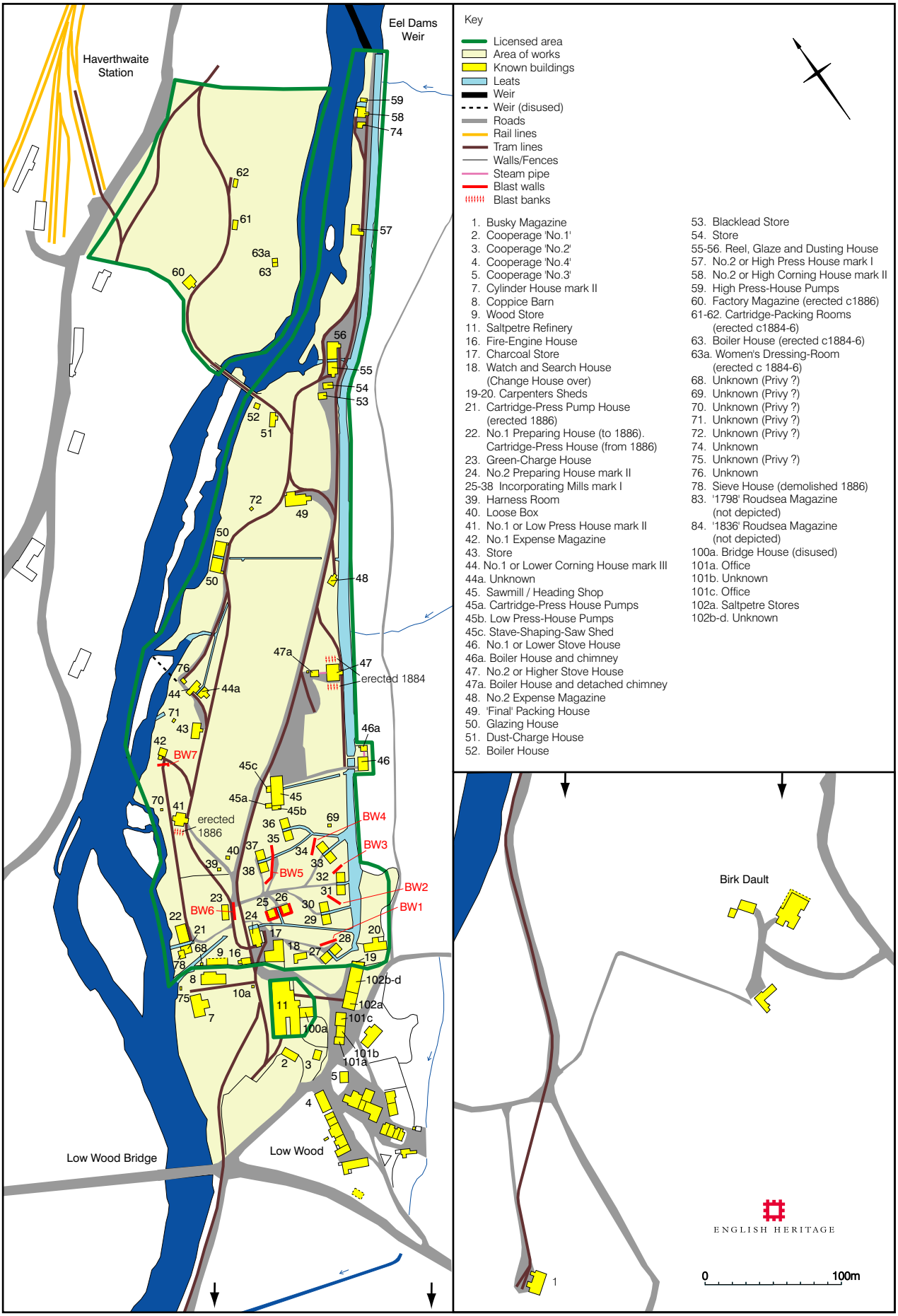


Fig 138. EH phase diagram of the gunpowder works, c 1882-8

and 1888. Incorporating mills 25/26 were again affected by fire in 1887, but it was a flash ignition of accumulated powder which caused little or no damage to the machinery or buildings, although two maintenance workers caught by the flash died of burns and/or shock. The incident stands out because it blotted an otherwise much-improved safety record at Lowwood under Wakefield management: no further deaths occurred until 1903 (above, page 37, and appendix 1 below).

The terminal date of 1888 for this phase in Lowwood's history is a rather arbitrary one, chosen largely as the year in which the OS first edition 25-inch map (Fig 7) was surveyed: the map provides a snapshot in time of the works layout and also much of the evidence on which Fig 138 is based. Nevertheless, when compared against recorded developments which took place over the next thirty or so years (section 7.2.8 below), 1888 does indeed seem to mark the end of a major round of changes and improvements carried out by the new owners in order to bring the factory up to standard.

7.2.8 Into the 20th Century: the later years of the Wakefield takeover, 1889-1917 (Fig 139)

Documented innovations and improvements made by the Wakefield company at Lowwood after 1888 can be characterised as mostly small-scale technological developments in the field of power generation, and expansion in the stock of ancillary buildings. This is despite the fact that in 1903 the company was restructured into a public liability company with capital of £75,000 (above, page 37); much of the new capital may have been devoted to developing the Gatebeck side of the business rather than Lowwood. It is possible that the company also ceased in-house production and refining of the three ingredients of gunpowder (charcoal, saltpetre and sulphur) in this period, and came to rely instead on specialist manufacturers and suppliers; this had certainly happened by 1926.

As stated, technological improvements at Lowwood between 1889 and 1917 seem to have been confined to the area of power generation. The works acquired its first turbine as early as 1872 (section 7.2.6 above), but by 1910 had invested in at least two more. Documents hint that the company converted the glazing house from waterwheel to turbine operation in 1903 (above, pages 37 and 61), but unfortunately the case cannot be proved or disproved from the surviving ruins of the building as a more powerful unit was installed in 1928/9 which has destroyed any physical evidence (above, pages 120-1). Two units were definitely installed in 1910, however: one replaced the sawmill waterwheel, while the other reportedly generated electricity (above, pages 61-3). The date Lowwood first acquired electric lighting is unclear. Tyler has stated that it happened in 1888, but the present report has shown (above, page 37) that all that can in truth be said given the current state of evidence is that electricity arrived at the works sometime between 1889 and 1910. Certainly the second of the two turbines acquired in 1910 seems to have been intended to power a dynamo, for George Shackley remembered that the machinery was sited in a shed attached to the outside of the old charcoal store, but it is unclear whether this turbine was a replacement unit or heralded the first introduction of electric power. The turbine also drove a stave-hollowing machine in an adjacent shed, and reportedly was insufficiently powerful to operate both dynamo and stave-hollower simultaneously (above, pages 62-3). EH has found evidence which suggests that this state

of affairs persisted right through the Wakefield years and beyond, and was not finally remedied until 1928 (section 7.2.10 below).

Evidence for additions and changes to the stock of buildings at the works is mostly derived from comparison of the first two editions of the OS 25-inch maps surveyed in 1888 and 1911 (Figs 7 and 8). Development is most noticeable around the sawmill, where a number of new sheds - reportedly housing various types of saws and lathe (above, pages 159-61) - had been tacked on to the outside of the building and at least three new structures (nos. 10, 65 and 77) erected in the vicinity before 1926. The second of these three structures housed a travelling saw (above, pages 163-4). Although building 10 mark I and building 77 had been replaced or demolished by 1926, they have both been interpreted here as wood stores (pages 168-9 and 177). The maps indicate that a second wood store at the works (building 9) was also extended slightly between 1888 and 1911. This suggests that the company was choosing to invest in facilities for the maintenance of the works and for the manufacture of the barrels and boxes in which the loose powder and cartridges were packaged, but there is no evidence, either in the documents or the physical remains of the buildings, that they were making much investment in new machinery or trying to increase production in this period. Indeed, to the contrary, the lower stove house appears to have been reduced in size around 1911 (above, page 124).

It has also been argued in this report (pages 63-4, 65-6 and 69) that by 1926 Lowwood had stopped in-house production of charcoal and ceased refining its own saltpetre, and had instead switched to obtaining supplies of both materials from specialist producers; in the case of saltpetre, potassium nitrate was being brought in from Lowwood's sister factory in ICI's North of England Gunpowder Group: Gatebeck. The exact date or dates of the switch - which may have been different for each of the ingredients - is unknown, but the move away from self-reliance is likely to have started, if not to have been completed, within the phase under review. Indeed, it has been suggested (page 66) that the Lowwood saltpetre refinery may have been disused as early as 1888, since Lowwood and Gatebeck were united under a single ownership from 1882. In the case of charcoal production, such an early date would fit in with a pattern known from the other Cumbrian gunpowder works: Elterwater reportedly ceased producing its own charcoal as early as 1866 (Marshall and Davies-Shiel 1969, 77), New Sedgwick possibly as early as 1884 following a fire, but certainly no later than the early 20th century (Dunn *et al* 2003, 38), and Blackbeck between 1898 and 1911 (Dunn *et al* 2005, 44). The situation regarding saltpetre is not so clear-cut: Elterwater was apparently still refining its own potassium nitrate in 1925, but was using sodium nitrate brought in from New Sedgwick (Jecock *et al* 2003, 38); New Sedgwick was presumably still purifying both forms of saltpetre, therefore; there is no evidence that Blackbeck ever had its own refinery, although it is not totally impossible that the building called the saltpetre house (Dunn *et al* 2005, 41-3) doubled up as both store and refinery. There is virtually no evidence for where or in what state Lowwood obtained its supplies of sulphur at this time, but by 1925 Elterwater was importing pre-refined sulphur from Texas (Jecock *et al* 2003, 38). It seems likely that even if Lowwood used a different supplier to Elterwater, it would nevertheless have been importing sulphur in a similar, refined state by this time.

At the outbreak of war in 1914, Lowwood may well have increased production at the Government's direction, for although blackpowder was no longer much used as a missile propellant, it was still in demand for other military equipment such as signal rockets and time fuzes (Cocroft and Tuck 2005, 229). It is likely, however, that this was achieved by expanding shift working, moving to round-the-clock production or by extending the length of the working week, and not by investing in additional plant or new machinery. Unfortunately there is very little surviving correspondence for the war years in the Heritage First! archive, although one letter (LW/1901/031) does record the rejection of a delivery of blackpowder from Lowwood to the Royal Arsenal in Woolwich in 1916. The nearby Blackbeck gunpowder factory reportedly constructed 'a new reel and cracking house … in 1915' (Dunn *et al* 2005, 154), suggesting that it too was producing powder under Government contract.

7.2.9 Post-War Difficulties: the formation of Explosives Trades and Nobel Industries Ltd, 1918-26 (Fig 140)

In 1918 all four gunpowder companies with factories in Cumbria merged as part of a new national conglomerate called Explosives Trades Ltd, which in 1920 became Nobel Industries Ltd (above, pages 2 and 38), although Dunn has recently noted that the generally accepted story of who took over whom and when may not be quite so clear cut as is often assumed (Dunn *et al* 2005, 20). The merger was in response to overcapacity in the explosives industry generally brought about by the gearing-up of production levels to meet wartime demands. Elsewhere in England, factories voluntarily went into liquidation as part of an agreed programme to address the problem of oversupply - for example Chilworth closed in 1920 (Cocroft and Tuck 2005, 231) - but the process of rationalisation did not directly affect the Cumbrian blackpowder factories until 1928. In the interim in 1926, Nobel Industries became a subdivision of Imperial Chemical Industries (ICI).

There is very little that can meaningfully be said about developments at Lowwood in the years between the ending of the Great War and the creation of ICI. Correspondence from this period in the Heritage First! archive consists almost entirely of reports made in 1918 by one T H Curtis on some of the American gunpowder works, and letters exchanged in 1919-20 between the various gunpowder factory owners and their workforce (represented by the National Amalgamated Union of Labour) over wages and the length of the working week: the disputes seem to have been settled amicably, mostly by referral to the Court of Arbitration (HF LW/1901/035-060). The only real evidence for developments within the factory in this period, therefore, is the 1926 factory plan (Fig 9) which provides a snapshot of the state of the works at its absorption into ICI. But although slight differences are apparent compared to the factory layout recorded by the OS in 1911 – such as the replacement of building 10 mark I by a smaller building, the demolition of building 77, and the construction of a heated stave-drying shed (buildings 66 and 67) - it is impossible to know with any certainty if the changes date to before, or after, 1918. It may be instructive, therefore, to look away from Lowwood to what was happening in one of the Cumbrian blackpowder industry's traditional markets. The slate quarries of North Wales, for example, had been regular customers of Lowwood blasting powder before the war, and certainly for a time in the last quarter of the 19th century the company had operated its own steamer, *Leven*, specifically to service this

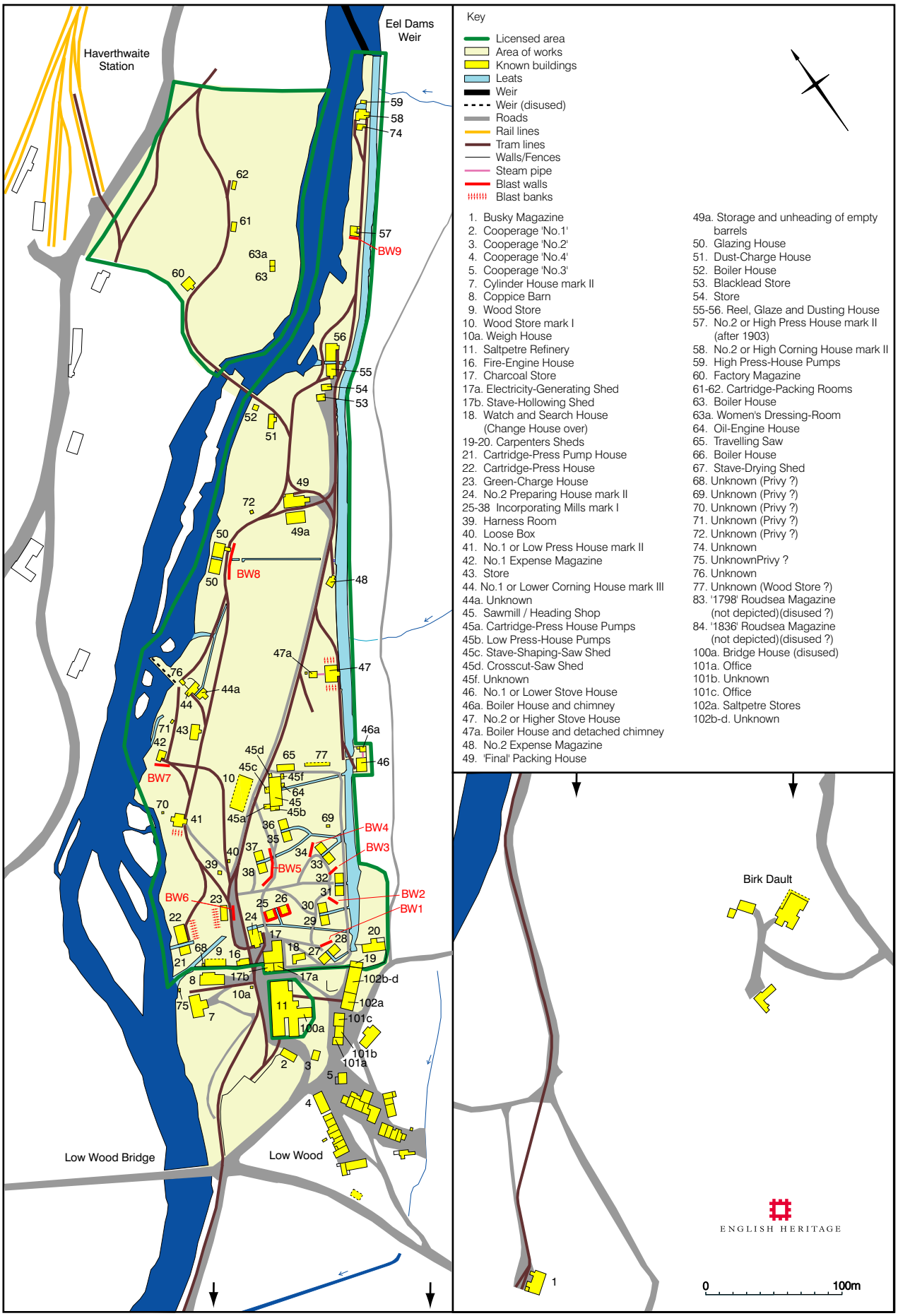


Fig 139. EH phase diagram of the gunpowder works, c 1889-1917

trade (above, page 179). But the Welsh slate industry was very slow to recover after 1918, mainly due to labour shortages and increasing competition from other roofing materials but also because it had lost one of the largest of its own traditional export markets - Germany (Richards 1995, 164-80). We might predict that this would have had serious knock-on effects for all of the blackpowder manufacturers in Cumbria. Taken together, therefore, the meagre strands of available evidence all suggest that these must have been difficult years at Lowwood, with little or no investment in the means of production.

7.2.10 Investment and Rationalisation: the ICI years and closure, 1926-35 (Fig 141)
Things started to change radically after 1926 when Nobel Industries became part of ICI. Although details of ICI's commercial strategy at this time have not survived, it is evident that the company rapidly selected Lowwood as one of the factories in which it was prepared to invest whilst others - including two of its neighbours in Cumbria, Blackbeck and Elterwater - were shut down as part of the ongoing strategy to tackle the problem of surplus capacity in the explosives industry. As a first step, towards the end of 1927 ICI purchased the freehold of the Lowwood site from the Bigland family for the princely sum of £18,000. Then the company began to invest heavily in modernising and re-equipping the factory. The bulk of the investment seems to have occurred over the next two years, but small improvements were still being made in 1931 and possibly later. Some of the improvements have already been documented by the ICI historian and by Tyler (above, pages 38-9), but EH has been able to elucidate others for the first time from study of a set of photographs of the works taken in 1928 and 1929 which survive in the Patterson Collection at the NMRC; additional details have come from surviving archaeological evidence and analysis of standing structures at the site.

The greatest investment, and probably the first to be undertaken, was no doubt the rebuilding of the incorporating mills in 1928. EH has shown (above, pages 89-98) that this involved the demolition of five of the existing pairs of mills with wooden superstructures (nos. 27/28 to 35/36), and their replacement by single, stone chambers over basements; the chambers were designed to accommodate a new design of under-driven, edge-runner mill. Tyler (2002, 152) states that the edge-runner mills came from the Fernilee Gunpowder Works in Derbyshire, but since that factory reportedly closed in 1920 (Patterson 1986, 13 table 1), that would mean they must have been in use or in storage elsewhere in the meantime. The replacement edge-runner mills were of the more modern, suspended, type. They, and the mill buildings which housed them, were also authorised to incorporate 68.1kg of green charge at a time - almost double the previous authorised limit of 36.32kg (above, page 92) - meaning that the five new, mark II, incorporating mills could produce almost the same amount of ripe charge as the ten of the old, mark I, design which they replaced. Patterson (1995, 16) has written that of the two remaining pairs of incorporating mills at Lowwood, one was retained unmodernised and the other rendered obsolete, but does not make clear which was which. From study of the standing fabric, EH has been able to demonstrate quite conclusively that it was the remaining pair of mark I mills, nos. 37/38, which was kept, and that the old stone mills, nos. 25/26, were the ones retired from service. This is shown by the fact that the latter mills exhibit evidence of conversion to a different use which entailed the removal of the old central waterwheel from its pit and its replacement by a water turbine (above pages 87 Fig 41d, and 88-9). Although

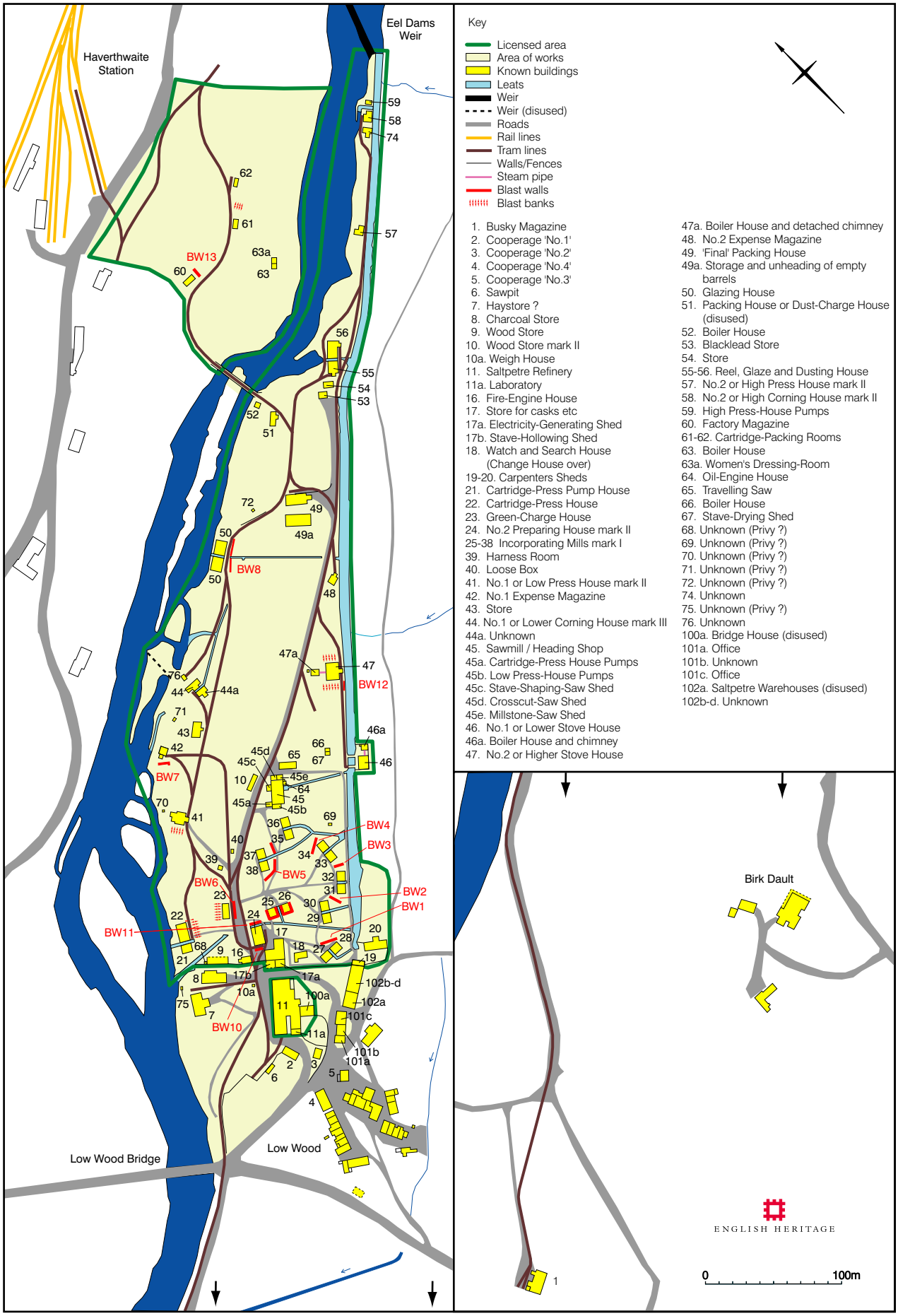


Fig 140. EH phase diagram of the gunpowder works, c 1918-26

it is not certain what the new function of the mill buildings was, EH has suggested that it is most likely to have been electricity generation, thus solving the long-standing problem which Lowwood had of only being able to operate the existing generator when the stave-hollowing machine was not working (section 7.2.8 above). The reason why one pair of mark I mills was retained after 1928 may simply have been because there was no sixth suspended edge-runner mill available from Fernilee to replace them, if indeed the edge-runner mills did come to Lowwood from Derbyshire.

Prior to the present investigation, there seems to have been no recognition in print of the fact that the lower corning house was totally rebuilt as part of ICI's refurbishment of the works, and that the standing structure is, therefore, the fourth corning house on the site and dates only from 1928 (above, pages 107-12). Furthermore, EH has been able to demonstrate that the extant structure appears to be of almost identical design to near-contemporary corning houses erected at two gunpowder works in Faversham in Kent, indicating that Nobel and/or ICI had by this time settled on a standardised layout for the corning house, and presumably therefore, on a standard design of corning machine also: the latter was said to be of 'Nobel' type.

Also prior to the present investigation, the only real evidence that the glazing house was included in this general refurbishment was a contemporary photograph published by the ICI historian captioned 'the Reconstructed Glazing House', and Tyler's statement – perhaps largely based on it - that sometime around 1928 'glazing drums were replaced by modern drums' (Imperial Chemical Industries 1929, 341 bottom; Tyler 2002, 152). However, aided by previously unpublished photographic evidence from the Patterson Collection, EH has been able to chart the degree of remodelling undertaken in 1928/9, and to show that what remains of the structure today retains elements of earlier phases also: parts of the fabric, particularly at basement level, must pre-date 1863 when the building functioned as the higher corning house (above, pages 105-7 and 114-21, especially Figs 65 and 66).

EH has also been able to expand on the manner in which both stoves at the works were modernised and adapted at this time. According to Tyler (2002, 152), both were scrapped around 1928 as a result of the installation of new glazing drums capable of removing most of the moisture from the powder, although his statement is at odds with the earlier account of Patterson (1995, 18-19) based on the MMB, which gives details of one stove still operational at Lowwood in 1933/4. EH has drawn on previously unpublished photographic evidence and on what survives structurally of the two stoves, to argue that the lower stove house was indeed closed down in 1928/9, but that its associated boiler house was retained and enlarged to accommodate a Robey stationary boiler which the company must have purchased secondhand. This boiler produced steam which was then piped to the former boiler house at the higher stove which now contained a steam turbine blowing hot air into the rebuilt higher stove house; the latter building was used exclusively for the drying of blasting cartridges (above, pages 122-36). Both stove houses are ruinous, but EH has also been able to demonstrate that both retain fabric and features from earlier phases dating back to at least the mid-19th century; in the case of the boiler house at the lower stove, some of the fabric arguably dates back to when the building was first erected in 1799.

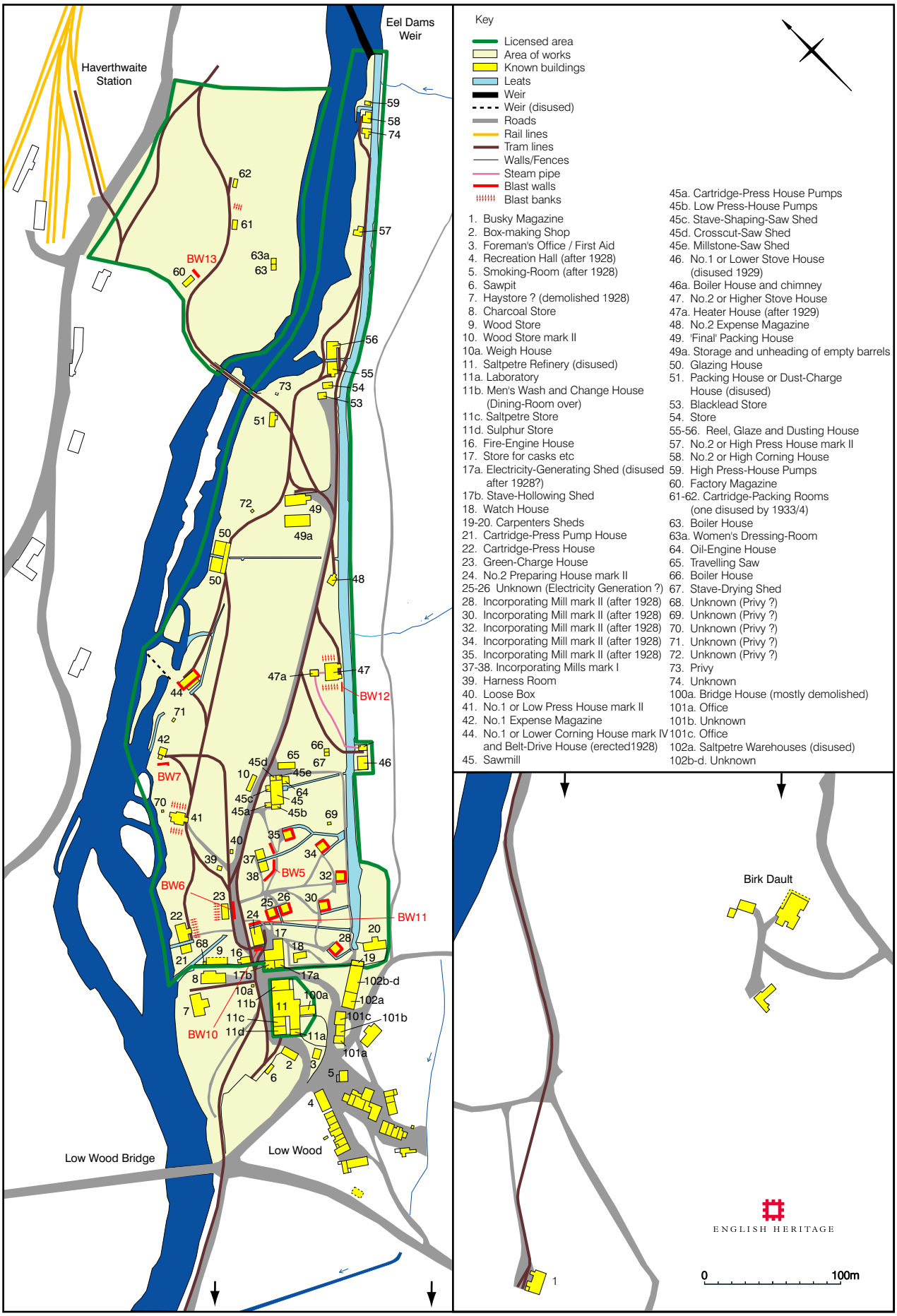


Fig 141. EH phase diagram of the gunpowder works, c 1926-35

Other improvements which occurred at or shortly after this time, and which were already documented in the published literature, include the installation of new reels at the reel and glaze house in 1931-2 (Patterson 1995, 18), and the creation by 1929 of recreation and mess rooms and of improved washing and changing facilities for the workforce (Imperial Chemical Industries 1929, 342). The reel and glaze house no longer survives above foundation level, and EH has been unable to add significantly to what is already known (above, pages 121-2). But by combining previously unpublished eye-witness and archival sources with slight structural evidence, EH has been able to suggest, and in the case of the wash house confirm, the location of these new welfare facilities while at the same time shedding light on the later histories of several buildings, particularly the saltpetre refinery (above, pages 69, 71, 77, 156 and 174) and a couple of the cooperages (above, pages 166-8 and 174).

EH has also found evidence in the Patterson Collection to indicate that further improvements should be added to the already long list of known investment carried out by ICI in 1928-9, namely: the rebuilding of the cartridge-pressing house (above, pages 149-51), and of the tramway bridge across the River Leven. A number of alterations to the network of tram lines around the factory also appear to date from this time (above, pages 181-3). However, despite this massive investment in plant and machinery and improvements made to working conditions at the factory, ICI was unable to prevent a continued decline in demand for blackpowder, and in May 1935 finally ceased production at Lowwood. Thus ended a tradition of blackpowder manufacture in the Leven valley which had endured, unbroken, for almost 136 years.

7.3 The Post-Gunpowder Landscape

7.3.1 World War II, 1939-45

Only four months after closure, in October 1935, ICI sold the physical assets of the Lowwood company - including all the buildings, some of which were already ruinous through having fires set to cleanse them of powder residues – to one Augustus While (above, page 39). While does not seem to have done much with the main factory site straightaway, and may initially have been more interested in the workers' houses in Low Wood hamlet. EH has found evidence for Nissen and Romney huts and other military structures on the main factory site (above, pages 196-8), however, which shows that when, or shortly after, war broke out yet again a few years later in 1939, the disused works was requisitioned by the Government.

It is not entirely clear to what use the Government put the Lowwood site. EH has conducted no research into wartime documents which might exist at the National Archives in Kew, but according to local residents the factory became either a camp for Italian prisoners-of-war or a small army base (above, page 196). The balance of evidence favours the latter interpretation, for the presence at Lowwood of features which EH has interpreted as a Romney hut/vehicle workshop facility and a fuel dump (above, pages 197-8) might be considered unlikely installations on a prisoner-of-war camp. An alternative possibility is that these particular features represent a different phase of use of the site, unrelated to the many Nissen-hut bases which are also present. The army personnel and/or PoWs probably made use of the washing and toilet facilities installed by ICI in 1928/9 in the disused saltpetre refinery.

7.3.2 Power Generation and Caravan Park, 1952 onwards

Since 1952, the family and trustees of Augustus While have sought to exploit the factory's potential for water power to generate electricity. The electricity produced was initially for local consumption in Low Wood hamlet, and EH has identified an Armfield water turbine installed in the basement of incorporating mill 36 mark I as most probably connected with that activity, although EH has also speculated (pages 97-8 and 198-9) that the turbine might be that originally bought by ICI in 1928 and used elsewhere in the gunpowder factory prior to being resited to its present location after 1935. This turbine is now disused, and electricity produced instead by a small hydro-electricity station erected close to the former position of the cartridge-press house; the output is sold to the National Grid. The installation of this power plant has involved, at different times, the raising, relining and in part re-routing of the main headrace in order to deliver a sufficient head of water to it. The re-routed part of the headrace is retained by a massive embankment. Although the sites of several gunpowder buildings lie in its path (compare any of the phase diagrams Figs 132-41 with Fig 142), stretches of stone walls visible in the sides and near the base of the embankment (for example buildings 17, 8, and 16 - above, pages 53, 64 and 170) suggests that rather than being completely demolished some if not all the buildings were buried as they stood when the embankment was first constructed in 1952/3. The subsequent raising of the water level in the leat in the 1960s does seem to have led to the demolition of structures situated on the thin spit of land between the headrace and river at the top end of the site, however; any surviving remains were further buried beneath dumping brought in to shore up the sides of the heightened headrace (high press and corning houses, above, pages 103-4 and 112-14). The raising of the level of water in the headrace now causes occasional winter flooding of the restored boiler house at the lower stove, which contains the Robey boiler installed in 1928/9 (above, page 129).

The owners have also let part of the former licensed area for eight static caravans and two builder's yards. Although these uses have had minimal impact on archaeological survival, small areas of damage which are evident around the site, particularly in the vicinity of the higher stove and between the sites of the cartridge-press and green-charge houses, are undoubtedly attributable to one of the builder's yards, as are a number of dumps of stone rubble and other material in the vicinity of the 'final' packing house.

Otherwise, the major threat which now faces the site is one of benign neglect: most of the former licensed area of the gunpowder works is overgrown with scrub and unmanaged woodland. Areas around the incorporating mills, lower corning house, glazing house and lower stove house were cleared in 2004 as part of the present programme of investigation and recording, but vegetation is already beginning to grow back and obscure the archaeology once more. Although this re-growth is mostly cosmetic, it does include several trees rooted in the tops of some of the incorporating mills (above, pages 84-5) which will eventually cause major structural damage. Ruined buildings and archaeological remains elsewhere across the site are increasingly at threat from wind-thrown and rotting trees, plus the inevitable long-term effects of frost and rain on stone and concrete.

8. SURVEY METHODOLOGY

The main site plan was produced via conventional land-based rather than satellite survey techniques because of the dense tree cover on site, although limited use was made of Global Positioning System (GPS) equipment to position the survey accurately within Ordnance Survey National Grid and also to tie in a number of survey stations which lay divorced from the main traverse.

In total, a network of 42 survey stations was established across the site using a Trimble 5600-series total station theodolite. This consisted of a primary ring traverse supplemented by a number of link traverses, spur stations and divorced two-station baselines. Before any observations were taken, station 1 which lay in a more elevated part of the site with less tree cover and therefore better satellite visibility, was selected to act as a local base station from which to bring in National Grid (NG) coordinates using a dual-frequency Trimble 4800-series GPS receiver and the Ordnance Survey's active-GPS station network. NG coordinates were successfully computed using Trimble Geomatics Office (TGO) software and the OSNT02 transformation, employing broadcast rather than precise ephemerides: the standard Chi-square test was passed after a single iteration of the adjustment routine using an alternative scalar weighting strategy. Differential-GPS surveying relative to station 1 was then undertaken to record NG coordinates for seven other station set-ups at the clearer, south-west end of the site, in order to obviate the need for traversing through these with the total station, as well as providing a reference bearing from which to carry NG coordinates round the main traverse. However, station 8 which lay closest to tree cover, was subsequently found to have incorrect coordinates (most probably due to branches interrupting satellite line-of-sight), necessitating its re-observation by theodolite as part of an additional link traverse. Station positions were adjusted using least squares, the maximum misclosure being 35mm horizontal, 60mm vertical, and 198 seconds of arc, although errors generally were much better than this. Twelve of the 42 stations were marked by survey nails or rivets drilled into stone whilst another utilised part of an existing water stopcock/meter cover, and so could be considered to be permanently marked. However, since the local site base, station 1, could only be marked by a wooden peg because of ground conditions, coordinates and guides to relocating these thirteen permanently marked stations are not included in this report, although that information is retained in the site archive. Points of archaeological and topographical detail were subsequently observed by radiation from each of the station set-ups, and coded with line and point information before being loaded into an AutoCAD dwg file. All theodolite data were processed using Trimble Geosite Office software, with distance measurements reduced by a local scale factor of 0.99966, or -340ppm.

Plots of the observed data at a variety of scales between 1:100 and 1:500 were then taken back into the field for checking, and missing detail added using standard graphical techniques of offset and radiation. New information was digitised into the main AutoCAD file.

Survey of upstanding masonry was for the most part undertaken by hand in the field using tape, measuring stick and booked data, with limited use of reflectorless electromagnetic distance measurement (REDM) to assist in recording building elevations. All these data were subsequently drawn up electronically in the office within a Microstation environment.

9. ACKNOWLEDGMENTS

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Archaeological investigation at Lowwood (that is, production of the overall site plan and investigation, recording and analysis of earthwork and lesser architectural features) was carried out by Marcus Jecock, Christopher Dunn, and Philip Sinton, aided for a short while by Eleanor Kingston of the LDNPA; architectural recording and analysis of the standing roofed buildings and more substantial ruined structures was conducted by Dr Ian Goodall, Simon Taylor, Tony Berry and Nigel Fradgley. The report has been mainly researched and written by Marcus Jecock, with assistance on the documentary side from Amy Lax and Abby Hunt, and contributions on the surviving architectural components from Ian Goodall (ironworks buildings, saltpetre refinery, charcoal stores, lower corning house mark IV, glazing house, lower and higher stoves, Busky magazine, cooperages and Birk Dault) and Simon Taylor (incorporating mills and the remaining buildings of Low Wood hamlet). Tony Berry has elucidated the technological clues contained within the architectural evidence, and transferred that information to the plans, sections and elevation drawings of the saltpetre refinery, incorporating mills, lower corning house mark IV, glazing house, and lower and higher stoves. Philip Sinton is responsible for all other plans except Figs 90, 92 and 93 which were originally penned for archive deposit at the NMRC by Allan Adams. The text has been edited by Christopher Dunn and Ian Goodall. Other members of EH staff provided advice and assistance on various issues: Roger J C Thomas, military support officer, provided information on WW2 structures and methods of lightning protection; Dr Paul Barnwell, advice on interpretation of historic legal documents and how to calculate the modern equivalent of Victorian monetary values; Wayne Cocroft, advice and information on aspects of the Lowwood site and parallels elsewhere, particularly methods of saltpetre production at Waltham Abbey and the design of corning houses at Faversham; and Neil Redfern, information on the correct interpretation of World War II features at Jervaulx Abbey.

10. LIST OF REFERENCES

Published sources

Atkinson, T 1865, *Local Chronology: being notes of the principal events published in the Kendal newspapers since their establishment* (London: Hamilton Adams)

Awty, B G 1977, 'Force Forge in the Seventeenth Century' *Trans Cumberland Westmorland Antiq Archaeol Soc*, **77**, 97-112

Awty, B G and Phillips, C B 1980, 'The Cumbrian bloomery forge in the seventeenth century and forge equipment in the charcoal iron industry', *Trans Newcomen Soc*, **51** (1979-80), 25-40

Bowden, M (ed) 2000, *Furness Iron* (Swindon: English Heritage)

Brierley, H 1907, *The Registers of the Priory Church of Cartmel 1559-1661* (Lancashire Ph Register Soc, **28**)

British Geological Survey 1997, *Ulverston. England and Wales. Sheet 48 Solid and Drift Geology. 1:50 000*. (Nottingham: British Geological Survey)

Chitty, G 1996, *Monuments Protection Programme. The Gunpowder Industry: recommendations for protection (Step 4 report)* (Unpublished EH confidential internal document)

Cocroft, W 1994, *Oare Gunpowder Works* (Faversham: Faversham Soc Paper **39** in association with RCHME)

—— 2000, *Dangerous Energy* (Swindon: English Heritage)

Cocroft, W D and Tuck, C 2005, 'The Development of the Chilworth Gunpowder Works, Surrey, from the Mid-19th Century', *Industrial Archaeol Rev*, **27** (November 2005, No. 2), 217-34

Cossons, N (ed) 1972, *Rees's Manufacturing Industry (1819-20), Volume 4* (Newton Abbott: David & Charles reprints)

Crocker, A 1993, 'Liverpool Magazines: further information', *Gunpowder Mills Study Group Newsletter*, **13**, August 1993, 6-10

—— 2000, 'Early Water Turbines in the British Isles', *Industrial Archaeol Rev*, **22** (November 2000, No. 2), 83-102

Crocker, A and Crocker, G 1989, 'The Lowwood Gunpowder Works Clock' *Gunpowder Mills Study Group Newsletter*, **5**, February 1989, 5-6

—— 1992, 'Gunpowder mills of south Cumbria', *Gunpowder Mills Study Group Newsletter*, **11**, September 1992, 8-14

Crocker, G 1988a, *Gunpowder Mills Gazetteer* (London: Soc Protection Ancient Buildings, Wind and Watermill Section, Occasional Publication 2)

—— 1988b, The Lowwood Gunpowder Works: a short history (Cartmel: R E Harvey)

—— 1999, *The Gunpowder Industry* (Second edition) (Aylesbury: Shire)

Cumbria Family History Society 1991, *Transcript and Index of the 1851 Census for Allithwaite Upper and Lower, Cartmel Fell, Staveley, Broughton East and Upper Holker*

— 2003, *Transcript and Index of the 1851 Census for Lower Allithwaite, Lower Holker and Upper Holker*

Curtis, W S 1996, 'The deterioration of gunpowder and some of the methods that were used to combat it', in B Buchanan (ed), *Gunpowder: the History of an International Technology*, 253-9 (Bath: Bath University Press)

Department of the Environment 1987, *List of Buildings of Special Architectural or Historic Interest. District of South Lakeland, Cumbria (parishes of Cartmel Fell, Colton, Haverthwaite, Staveley-in-Cartmel and Upper Allithwaite)* (London: DoE)

Dunn, C J 2001, *English Heritage Archaeology and Survey Projects Division Step 4 Industrials Recording Programme Project Design. Project: The gunpowder industry module. Area: The Lake District* (version 3) (Unpublished EH internal document)

Dunn, C, Hunt, A, Goodall, I and Berry, A 2005, *Blackbeck Gunpowder Works, Cumbria: an archaeological and architectural survey* (York: EH Archaeological Investigation Report Series **AI/32/2004**)

Dunn, C, Lax, A, Berry, A, Goodall, I, Hunt, A, Jecock, M and Taylor, S 2003, *New Sedgwick Gunpowder Works, Cumbria: an archaeological and architectural survey* (York: EH Archaeological Investigation Report Series **AI/19/2003**)

Explosives Inspectorate 1878, *The Circumstances attending an Explosion of Gunpowder at a Gunpowder Factory at Elterwater, near Ambleside, Westmoreland, on the 29th November 1878* (London: HMSO)

—— 1887, *Report on the Circumstance attending an explosion Which took place in an Incorporating Mill at Lowwood Gunpowder Works on the 6th September 1887* (London: HMSO)

—— 1903, *Report on the Circumstances attending an Explosion which occurred in a Press House of the Factory of the Lowwood Gunpowder Company, at Lowwood, near Ulverston, Lancashire, on the 12th March, 1903* (London: HMSO)

Fell, A 1908, *The Early Iron Industry of Furness and District* (Ulverston: Hume Kitchin)

Gould, S 1993, *Monuments Protection Programme: The Gunpowder Industry. Combined Steps 1-3 Report* (Unpublished report for EH by The Cranstone Consultancy)

Guttman, O 1895, *The Manufacture of Explosives, volume 1* (London: Whitaker & Co)

Hunt, A and Goodall, I 2002, *Basingill Gunpowder Works and Garden, Cumbria: an archaeological and architectural survey* (York: EH Archaeological Investigation Report Series **AI/42/2002**)

Imperial Chemical Industries 1928, 'Blackpowder Group News', *ICI Mag*, March 1928, 214

——1929, 'Short histories of ICI companies: the North of England Gunpowder Group', *ICI Mag*, October 1929, 337-48

—— 1938, *ICI and its Founding Companies. The History of Nobel's Explosives Company Ltd and Nobel Industries Ltd, 1871-1926* (London: ICI)

Institute of Geological Sciences 1980, *IGS 1:250 000 series, Lake District sheet 54N 04W, solid edition* (Southampton: Ordnance Survey for IGS)

Jecock, M 1999, *Jervaulx Abbey, North Yorkshire* (York: RCHME = EH Archaeological Investigation Report Series **AI/4/1999**)

—— 2003, 'English Heritage's Cumbrian Gunpowder Industry Project', *Gunpowder & Explosives History Group Newsletter*, **6**, Spring 2003, 6-7

Jecock, M and Dunn, C, 2002 *Old Sedgwick Gunpowder Works: an archaeological and historical survey* (York: EH Archaeological Investigation Report Series **AI/11/2002**)

Jecock, M, Lax, A and Dunn, C 2003, *Elterwater Gunpowder Works, Cumbria: an archaeological and historical survey* (York: EH Archaeological Investigation Report Series **AI/9/2003**)

Joy, D 1983, *A Regional History of the Railways of Great Britain. Volume 14: The Lake Counties* (Newton Abbot: David & Charles)

Kelley, D W 1986, *Charcoal and Charcoal Burning* (Princes Risborough: Shire)

Kelly 1909, *Directory of Lancashire* (London)

Lister, S 1987, 'The Gunpowder Works Job', *The Iron Horse* (Journal of the Lakeside Railway Society), Spring 1987, 7-9

Mannex, P & Co 1866, *Topography and Directory of North and South Lonsdale, Amoundreness, Leyland and the town of Southport, &c* (Preston)

Marshall, J D 1975, 'Kendal in the late seventeenth and eighteenth centuries', *Trans Cumberland Westmorland Antiq Archaeol Soc*, **75**, 188-257

Marshall, J D and Davies-Shiel, M 1969, *The Industrial Archaeology of the Lake Counties* (Newton Abbott: David & Charles)

Ordnance Survey 1851, *County Series 6-inch, Lancashire sheet 12*. Surveyed 1848 (Southampton: Ordnance Survey)

—— 1890a, *County Series 25-inch, Lancashire sheet XII.2. First Edition*. Surveyed 1888 (Southampton: Ordnance Survey)

—— 1890b, *County Series 25-inch, Lancashire sheet XII.5. First Edition*. Surveyed 1888 (Southampton: Ordnance Survey)

—— 1890c, *County Series 25-inch, Lancashire sheet XII.6. First Edition*. Surveyed 1888 (Southampton: Ordnance Survey)

—— 1891, *County Series 25-inch, Lancashire sheet XII.9. First Edition*. Surveyed 1888-9 (Southampton: Ordnance Survey)

—— 1913a, *County Series 25-inch, Lancashire sheet XII.2. Edition of 1913*. Revised 1911 (Southampton: Ordnance Survey)

—— 1913b, *County Series 25-inch, Lancashire sheet XII.5. Edition of 1913*. Revised 1911 (Southampton: Ordnance Survey)

—— 1913c, *County Series 25-inch, Lancashire sheet XII.6. Edition of 1913*. Revised 1911 (Southampton: Ordnance Survey)

—— 1913d, *County Series 25-inch, Lancashire sheet XII.9. Edition of 1913*. Revised 1910-11 (Southampton: Ordnance Survey)

—— 1940, *County Series 25-inch, Lancashire sheet XII.2. Revision of 1938*. Revised 1938 (Southampton: Ordnance Survey)

Palmer, A 1998, *The Low Wood Gunpowder Company: its inception and early growth 1798-1808* (London: Gunpowder Mills Study Group/Soc Protection Ancient Buildings)

Patterson, E M 1986, *Gunpowder Terminology and Incorporation* (Faversham: Faversham Soc Paper **27**)

—— 1995, *Blackpowder Manufacture in Cumbria* (Faversham: Faversham Soc Paper **43**)

Phillips, C B 1977a, 'William Wright: Cumbrian Ironmaster', *Trans Lancashire Cheshire Antiq Soc*, **79**, 34-45

—— 1977b, 'The Cumbrian iron industry in the seventeenth century', in W H Challoner and B M Ratcliffe (eds) *Trade and Transport: essays in economic history in honour of T S Willan*, 1-34 (Manchester: University Press)

Powter, A 1981 'Concrete in nineteenth century fortifications by the Royal Engineers', *Fort*, **9**, 31-42

Public Statutes General 1860, **23 & 24 Victoria, c 139**; *An Act to amend the Law concerning the making, and Carriage of Gunpowder and Compositions of an explosive Nature, and concerning the Manufacture, Sale and Use of Fireworks* (London: HMSO)

—— 1875, **38 Victoria, c 17**; *An Act to amend the Law with respect to the manufacturing, keeping, selling, carrying, and importing Gunpowder, Nitro-glycerine, and other explosive substances* (London: HMSO)

Quayle, H 1977, 'The Low Wood Tramway', *Industrial Past* (Spring 1977)

RCHME 1996 *Recording Historic Buildings: a descriptive specification. Third edition* (Swindon: RCHME)

—— 1999, *Recording Archaeological Field Monuments: a descriptive specification* (Swindon: RCHME)

Richards, A J 1995, *Slate Quarrying in Wales* (Llanrwst: Gwasg Carreg Gwalch)

Slater 1890, *Slater's Royal National Commercial Directory of Lancashire, II* (Manchester)

Slater's and Kelly & Co 1895, *Royal National Directory of Lancashire, I,* (Manchester, Liverpool and London)

Smith, F M 1870, *Handbook of the Manufacture and Proof of Gunpowder, as carried on at the Royal Gunpowder Factory, Waltham Abbey* (London: HMSO)

Stockdale, J 1872, *Annales Caermoelenses, or Annals of Cartmel* (London: Simpkin, Marshall & Co)

Taylor, A 2004, *The Websters of Kendal. A North-Western Architectural Dynasty* (Kendal: Cumberland Westmorland Antiq Archaeol Soc Record Ser **17**)

Trueman, A E 1971, *Geology and Scenery in England and Wales* (Harmondsworth: Penguin)

Tyler, I 2002, *The Gunpowder Mills of Cumbria* (Threlkeld: Blue Rock Publications)

Wardell, W H 1888, *Handbook of Gunpowder and Guncotton* (London: HMSO)

Whyte, I 2003, *Transforming Fell and Valley. Landscape and Parliamentary Enclosure in North West England* (Lancaster: Centre for NW Regional Studies)

Wilson, P N 1964, 'The gunpowder mills of Westmorland and Furness', *Trans Newcomen Soc*, **36**, 47-65

Manuscript sources and newspapers

Cumbria Record Office, Barrow (CRO(B)):

BDKF/241/1 Title deeds and papers re Bigland Estate including Lowwood Gunpowder Works

BDKF/241/8 Grant of liberty to continue weir at Stangend in the parish of Colton, 1786

BDKF/241/9 Answer from John Bigland to William Wright, *c* ?1680

Cumbria Record Office, Kendal (CRO(K)):

WD BGLD 2420 Box 2. Bundle labelled 'Lowwood Estate & Furnace 1741-1897'

Brief seeking legal opinion over terms of Lowwood lease. Undated [*c* 1798?]

Counterpart lease of Lowwood Estate and Works. George Bigland Esquire to Mr Barker and others. 31st Jan 1799

Release and Covenants relating to the Lowwood Furnace and Estate. George Bigland Esquire to John Machell Esquire & George Knott Esquire and others. 13th Feb 1799

Counterpart lease of Lowwood Estate and Works. George Bigland Esquire to Mr Barker and others. 22nd December 1827

Counterpart Lease of Low Wood Gunpowder Works in the County of Lancaster. George Bigland Esquire to Jacob Wakefield Esquire and others. February 1897

WDY/448 Facsimile copy of David Huddlestone & Co's letter book, 1826-9

WPR/89 PR/2716/9 Plan of Bigland Estate, nd. Scale 6 chains to 1"

WPR/89 Z3 Cartmel inclosure award 13 Oct 1809, with plans of Staveley, Lower Allithwaite, Broughton, Cartmel Fell, Lower Holker, Upper Holker and Upper Allithwaite, surveyed by T Hornor, 1807

Mike Davies-Shiel Collection (in private possession)

Full details not known, but extracts supplied to EH include colour slides, notes, annotated plans, and copies of correspondence with the late George Shackley

Hampshire Record Office (HRO):

38M 90/D2 Additional records of J J Armfield of Ringwood

1. List compiled by A Yoward in 1990-1, of information on water turbines manufactured by Armfield of Ringwood during the period 1919-54

Robert Harvey Collection (in private possession)

Album of site photographs taken in the 1970s

Heritage First!, Ulverston (HF):
Collection of original company letter books and other documents, seen as a series of electronic transcripts (file nos. in parentheses)

Copy Tissue Book 957 Years 1865 to 1867 (L957)

Copy Tissue Book 958 Years 1865 to 1867 (L958)

Copy Tissue Book 959 Years 1879 to 1925 (L959)

Incoming Documents Years 1850 to 1859 (L1850-59)

Incoming Documents Year 1860 (L1860)

Incoming Documents Year 1861 (L1861)

Incoming Documents Year 1862 (L1862)

Incoming Documents Year 1863 (L1863)

Incoming Documents Year 1864 (L1864)

Incoming Documents Year 1865 (L1865)

Incoming Documents Year 1869 (L1869)

Incoming Documents Years 1870 to 1878 (L1870-78)

Incoming Documents Years 1884 to 1896 (L1884-96)

Incoming Documents Years 1901 to 1929 (L1901-20)

Miscellaneous Documents (LMiscell)

ICI, Ardeer:
Paper copy of plan at approximately 8 inches to the mile, entitled 'Block Plan of Lowwood Factory, HO/D 15-142', traced 28 July 1926, and annotated 'Factory No. 23 Lancs, Plan to Amending Licence No. 3034' and signed by 'H E Watts, HM Inspector of Explosives, 6 November 1926'.

Lancashire Record Office, Preston (LRO)
DDLO/26/1 Bundle of receipts for payments made by the Low Wood Gunpowder company to various people, Oct-Dec 1798

DDLO/34/3 Continuation of a lease for 50 years of a messuage at Low Wood known as Low Wood Powder Works for a further 50 years from the expiration of the current lease (recited)

DDX/116/14 Letters to C J Clarke of Lancaster, solicitor, from John Barker of Broughton Lodge and Lowwood Gunpowder Mills, concerning the gunpowder mills, 1858-63

QSP/2488/18-20 Receipt of Thomas Hamor (?Horner) for making plans and surveying Low Wood bridge, 29 Aug 1803

QSP/4159/15 Letter of application of Lowwood Gunpowder Company near Kendal *re* laying of tram rails on approach to Lowwood Bridge, 5 Oct 1883

QSP/4159/16 Letter of Lowwood Gunpowder Company near Kendal, to Clerks of the Peace *re* laying of tramway adjoining Haverthwaite Station, 12 Oct 1883

QSP/4159/18 Resolution that permission be granted to Lowwood Gunpowder Company to lay tram rails on approach to Lowwood Bridge near Haverthwaite Station, *c* 1883

Kendal Reference Library:
Westmorland Gazette, 19 July 1823, nd

Westmorland Gazette, 8 March 1862, page 4

Westmorland Gazette, 7 February 1863, page 4

Westmorland Gazette, 14 February 1863, page 6

Westmorland Gazette, 5 December 1868, page 5

Westmorland Gazette, 11 March 1871, page 6

Westmorland Gazette, 18 March 1871, page 5

Westmorland Gazette, 14 March 1903, page 8

Westmorland Gazette, 28 March 1903, page 6

Westmorland Gazette, 6 August 2004, nd

Ron Mein Collection (in private possession)
Full details not known, but extracts supplied to EH include the original of the 1846 plan, and copies of historic photographs and postcards and his own reconstruction drawings of the layout of the sawmill and mark II incorporating mills

NMRC Swindon:
Air Photographs Library
106G/UK653, frame 3112, 13 Aug 1945

541/525 frames 3306-7, 14 May 1950

National Buildings Record

File index no. 95781 Gunpowder Magazine, Roudsea Wood, Haverthwaite, Cumbria: Architectural Survey Report

File index no. 103349 Bark Barn, Roudsea Wood, Haverthwaite, Cumbria: Architectural Survey Report

Edward Patterson Collection (PAT01)

Box 1

1. Typescript list of documents deposited at the Lancashire Record Office

2. Original typescript of ICI's Manufacturing Method Book (MMB) for Lowwood

3. Envelope of black-and-white prints and negatives labelled 'Photographs: Lowwood Works, during and after reconstruction 1928-9'

Alice Palmer Collection (in private possession)

Full details not known, but extracts supplied to EH include photographs and slides taken in 1968-9

Brian Patrick Collection (in private possession)

Six envelopes (only one listed below) containing bundles of miscellaneous correspondence dated 1860-2

1. Five letters dated between 31 May 1861 and 17 September 1862 from Messrs Hopkinson & Cope, of the Albion Factory, 14 New North St, Finsbury, London, to Daye Barker, in envelope labelled 'Contract for Hydraulic Press'

While Estate Trustees Collection (Hart Jackson and Sons, Solicitors, Ulverston)

Site deeds

Loose documents:

Indenture 20th November 1882 between Lowwood Gunpowder Co Ltd and W H Wakefield, Reginald Crooke and John Wakefield Weston, gunpowder manufacturers. Price £8000.

Conveyance 1 October 1935 between Nobel's Explosives Co Ltd and Augustus While. Sale of Lowwood site for £1720.

Abstract of Title of Nobel's Explosives Co Ltd to freehold premises at Lowwood Lancashire, 1935. Schedule 2 includes notice of Indenture dated 16 April 1884 between Frederick Barker and W H Wakefield for sale of 785 square yards of land being part of Stang End Wood…and also a piece of Bleaberry Holme Island. £49 5s 0d.

Land at Backbarrow and Haverthwaite. Trustees of A While to Ministry of Transport. Payable order £773 5s 5d. 6 April 1965.

Bundle labelled: 'A While Esq. Prior deeds relating to property at Lowwood, Haverthwaite and Brow Edge purchased from Nobels Explosives Co Ltd'
Conveyance 16 November 1927 between Alfred Bigland and Reuben O'Neill Pearson (vendors) and W H Wakefield Co Ltd (purchasers). Sum £18000.

Conveyance 6 March 1871 between David Ainsworth Esq et al (vendors) to Lowwood Gunpowder Co Ltd (purchasers), of a dwellinghouse and land at Lowwood, price £1400.

Bundle labelled: 'A While Esq. Bundle of old deeds relating to Lowwood property'
Lease of Low Wood Estate and Works for 50 years from the 13 February and 12 May 1849. George Bigland Esq and another to Daye Barker and Christopher Wilson Esquires. Dated 22 December 1827. Rent £270.

Lease of land situate in the township of Upper Holker in the Parish of Cartmel in the County of Lancaster for 38½ years from 12 November 1861. The Trustees of the late George Bigland Esq and another to Messrs Daye Barker Company. Dated 20 June 1861. Rent £30 per year.

Agreement for the sale of Leasehold Premises Stock in Trade Goodwill and Fixtures. Messrs John Barker, William Wilson and James Christopher Wilson to the Lowwood Gunpowder Company Ltd 1863.

Conditions of Sale. At the King's Arms Hotel in Ulverston in the County of Lancaster 21 October 1863. Sale by auction by James Caddy Mann of Kendal and Isabella ?Towson. Lot 2. Three closes of land at Stang End to the Lowwood Gunpowder Co for £455.

Resolution of Justices of the Peace made at General Quarter Session at Lancaster 15 October 1883 granting permission to the Lowwood Gunpowder Co Ltd to lay tramrails across the approach to Low Wood Bridge and also across the Main Road near Haverthwaite Station.

Agreement between the Furness Railway Company and the Lowwood Gunpowder Company. 28 January 1884.

Memorandum of terms of renewal of lease of Lowwood Gunpowder Works. George Bigland Esq and Messrs W H Wakefield & Co. 6 October 1896.

Lease of Lowwood Gunpowder Works, Haverthwaite in the County of Lancaster. Mrs Audrey Bigland to Messrs W H Wakefield & Co Ltd, and others. 28 November 1916. Rent £1100.

Appendix 1: List of recorded accidents and explosions at Lowwood

It was only with the passing of the Explosives Act in 1875 that the reporting of fires and accidents involving explosives at gunpowder works became a statutory requirement (Cocroft 2000, 99). As a result, all major incidents after 1875 are recorded and analysed in great detail in a series of special reports prepared by Her Majesty's Explosives Inspectorate. Before that date, the only accident record we have for most of the Cumbrian blackpowder factories is local newspaper coverage of the most serious incidents - mostly those involving fatalities when a coroner's inquest would have been held. For Lowwood, however, we possess a considerable amount of original company correspondence which occasionally contains references to less serious incidents. It may be possible, therefore, to produce a fuller list of accidents at Lowwood, both major and minor, by a search of contemporary newspaper coverage and of the company archive, but systematic scrutiny of all such sources is beyond the remit of the present report. Accordingly, the following table lists early (pre-1875) accidents mostly, but not exclusively, where they are already noted in secondary sources. From 1876, even non-fatal minor explosions were noted briefly in the Explosives Inspectorate's annual reports. It has not been possible to consult this report series at first hand, but Patterson (1986, 29) has compiled statistical data from them for explosions which occurred in incorporating mills whilst in motion, and these are included in the table below. (Other explosions caused by the incautious removal of trod from stationary mills - hard, adherent, powder which accumulated on the mill bed and edge-runners during incorporation - were not included by him in those statistics, and so do not figure below). Interestingly, a letter from George Jackson, works manager of Lowwood for a 21½ year period sometime prior to 1863, states that there were no accidents resulting in loss of life or major damage to structures during his tenure of the post (HF LW/1871/006). If so, it is likely that the list is already complete as regards major explosions.

What the figures reveal is that explosions in incorporating mills were frequent, but did not regularly result in injury or loss of life because the dangerous nature of the process was appreciated, and the mill-keepers retired to the safety of the watch house after setting the mills in motion. However, other parts of the manufacturing process were equally dangerous, and occasionally went wrong with disastrous consequences. At Lowwood, as at works elsewhere, the chief culprit seems to have been the corning house, but having said that, Lowwod's safety record was broadly similar to other blackpowder works in Cumbria. Patterson (1995, 41-3) has compiled fatal accident statistics for all seven factories which operated in the county, and if we omit Basingill as being unrepresentative for the reason that only incorporation was undertaken there (Hunt and Goodall 2002) and Old Sedgwick for which there is no data (Jecock and Dunn 2002, 50), Gatebeck and Elterwater had slightly better safety records, averaging respectively 9.5 and 8 years per death against Lowwood's 6.5 years (Patterson's published total of 17 deaths for Lowwood at an average of 8 years per death omits the four fatalities which occurred in 1871). In contrast, Blackbeck had by far the worst record: during its relatively short operating life of *c* 69 years, 36 men died (*contra* Patterson's figure of 33), with the corning houses exploding nine times (Dunn *et al* 2005, 15 and 141-5).

(NB. n/d in the table overleaf indicates that no details are currently available)

Date	Site	Cause	Damage	Casualties	References
25 Sep 1799	Incorporating mill	n/d	Damage to millstones only	None	Palmer 1998, 47; Tyler 2002, 100
Jan 1800	n/d	n/d	n/d	None	Palmer 1998, 47; Tyler 2002, 100
27 Jan 1801	Incorporating mill	Loose iron bolt falling onto bedstone	Flash fire	None	Palmer 1998, 47; Tyler 2002, 103
?Nov 1801	n/d	n/d	n/d	1 man burned	Palmer 1998, 47
Aug 1802	Incorporating mill	n/d	Fire damage to building and edge-runners broken	1 man burned	Palmer 1998, 47; Tyler 2002, 104
Jan 1805	n/d	n/d	Flash fire	1 man burned	Tyler 2002, 105
14 Jul 1823	Higher Corning house	n/d	n/d	2 men killed	*Westmorland Gazette*, 19 Jul 1823; Atkinson 1865, 55;
1856	Incorporating mill?	n/d	n/d	1 man injured	HF LW/959/204; Tyler 2002, 117
2-3 Mar 1862	Mixing house and two incorporating mills	Fire	Buildings and machinery destroyed	None	*Westmorland Gazette*, 8 Mar 1862
29 Jan 1863	Explosion in glazing house, spreading to higher and lower corning houses and to low press house	?Incautious cleaning of glazing barrel	Buildings and machinery destroyed	6 men killed	*Westmorland Gazette*, 7 Feb 1863; *Westmorland Gazette*, 14 Feb 1863
22 April 1864	Corning house	n/d	Very little	None	HF LW/1864/067
18 May 1864	Incorporating mill	Failure to moisten charge	Damaged bedstones?	None	Tyler 2002, 121-2; HF LW/1864/083, 085, 086 and 173
20 Aug 1864	Incorporating mill	n/d	n/d	None	HF LW/1864/155
1864	Preparing House	n/d	n/d	1 man broke arm	HF LW/959/204
10 Apr 1866	Incorporating mill no. 37	?Loose wooden wedge jamming edge runners	Roof blown off and bedstone damaged	None	Tyler 2002, 125; HF LW/958/267
18 Dec 1866	Incorporating mill no. 29	Broken spindle	Roof blown off and side boards damaged	None	Tyler 2002, 127; HF LW/958/571

1866	Mill polisher	n/d	n/d	1 man injured foot	HF LW/959/204
28 Nov 1868	Corning house	?Foreign body in powder	Building and machinery destroyed	5 men killed	*Westmorland Gazette*, 5 Dec 1868;
26 Mar 1869	Corning house		Man trapped arm in rollers	1 man lost arm	Tyler 2002, 130; HF LW/959/204
8 Mar 1871	High (reserve) corning house	Unknown	Building and machinery destroyed	4 men killed	*Westmorland Gazette*, 11 Mar 1871; *Westmorland Gazette*, 18 Mar 1871; Tyler 2002, 131
1876	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
6 Sep 1887	Incorporating mill	Ignition of gunpowder dust during repairs to machinery	Flash fire. Very little damage to machinery or structure	2 men killed	Explosives Inspectorate 1887
12 Mar 1903	High (reserve) press house	?Foreign body in powder	Building destroyed	2 men killed	Explosives Inspectorate 1903; *Westmorland Gazette*, 14 Mar 1903; *Westmorland Gazette*, 28 Mar 1903
1907	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1908	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1913	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1914	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1917	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1918	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1920	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1920	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1920	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1921	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1927	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1927	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II
1927	Incorporating mill	n/d	n/d	n/d	Patterson 1986, table II

Appendix 2. The archive and photographic record

An archive of field survey plans and site photography, plus supporting background information such as the overall Project Design and selected correspondence, has been deposited with the NMRC in Swindon under Collections reference AF00198, where it is available for public consultation upon request. Survey data also exists digitally as a series of AutoCAD files, currently held at the EH office in York and also publicly available upon request.

The main photographic record of the site was taken by two EH photographers, Bob Skingle and Keith Buck, using Fuji S2 high resolution digital cameras as photographic job number 2K/09072. Each photograph has been allocated an individual NMR digital photograph (DP) number; many have been reproduced in some form in this report. Other 'snapshot' photography was taken during the course of investigation by Tony Berry, Christopher Dunn, Ian Goodall, Marcus Jecock and Simon Taylor using a range of lesser digital and film cameras. The images of the cylinder retorts at Ulverston and of historical plans at Kendal Record Office were taken by Marcus Jecock using a Fuji FinePix 1400Zoom digital camera, while plans accompanying the site deeds and images of the houses in Low Wood hamlet were photographed by Simon Taylor using a Canon PowerShotG2 4 megapixel digital camera. Pictures in this report accredited to Christopher Dunn and Tony Berry were taken on a Nikon 5700 and Nikon 5400 respectively, both 5 megapixel digital cameras. Photography accredited to Ian Goodall was taken on a conventional film camera. All these snapshot images - and others not reproduced in this report - are currently archived on CD or as prints at EH's office in York, and should ultimately also be available through the NMRC.

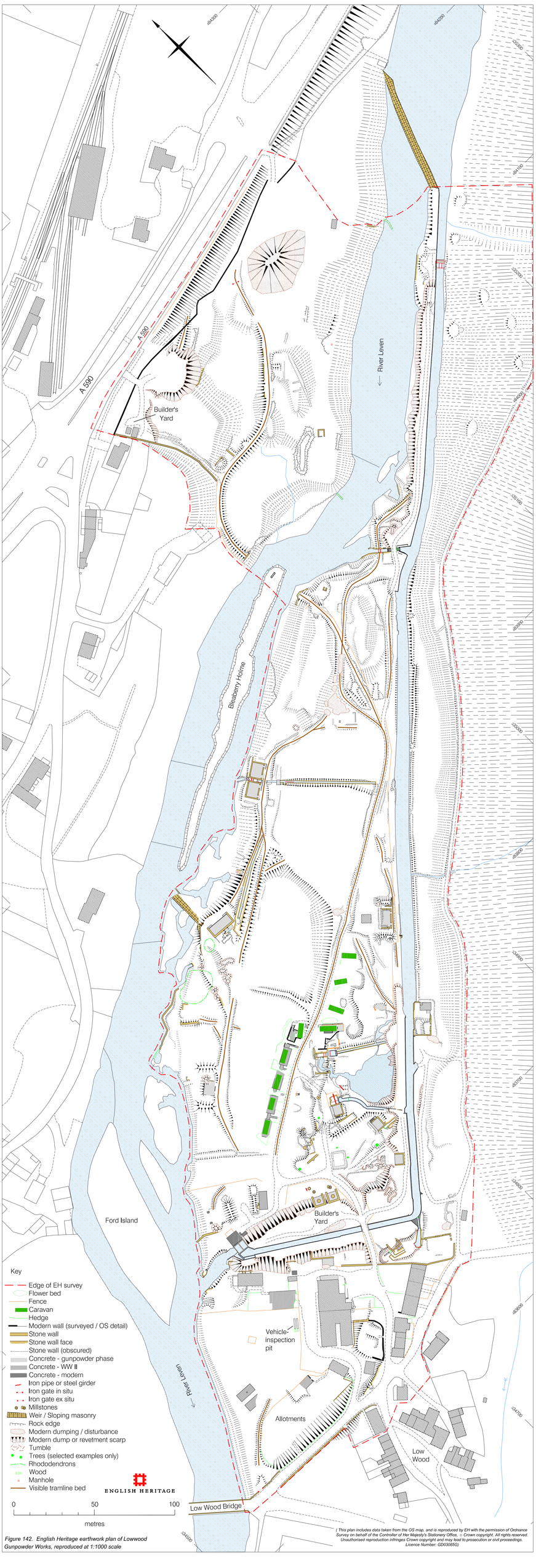

Figure 142. English Heritage earthwork plan of Lowwood Gunpowder Works, reproduced at 1:1000 scale

ENGLISH HERITAGE

NATIONAL
MONUMENTS
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The National Monuments Record
is the public archive of English Heritage.
It contains all the information in this report - and more:
original photographs, plans old and new,
the results of all field surveys, indexes
of archaeological sites and historical buildings,
and complete coverage of England in
air photography.

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