BACKBARROW PUG MILL, HAVERTHWAITE, Cumbria

Archaeological Assessment, Fabric and Turbine Survey Report

Oxford Archaeology North

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SUMMARY

An archaeological survey was undertaken of the Backbarrow Pug Mill, Haverthwaite, Cumbria (SD 3555 8470) in advance of a proposed commercial development of the site. A feature of this development was the conversion of the former Pug Mill for use as office accommodation. The work entailed the production of a documentary study specifically targeted on the Pug Mill, a fabric survey which enhanced existing architects drawings, and an assessment of the turbines on the site. The work was undertaken in December 2002, and an interim report was submitted in the same month. The present report is the final statement of the investigation results.

The Pug Mill is at the northern end of the Backbarrow iron working complex, which has been producing iron since 1685. The main episode of the iron manufacture, however, was from 1711 when a blast furnace was constructed on the site. Since then, the site has undergone many changes and developments, including the rebuilding of the blast furnace in 1870. In the 1920s the blast furnace was the last in the region to be converted from charcoal burning to coal burning. The works continued in operation until 1964 when it was closed.

The Pug Mill was an important development, located so as to exploit the River Leven water source, it would appear to correspond with the location of the original bloomery forge built by John Machell in 1695. With the construction of the blast furnace in 1711, a finery forge was established on the site, probably adapted from the original bloomery forge. In 1866 the Pug Mill was adapted to accommodate a 8.5hp water turbine in the place of a water wheel, and then a further turbine (of 40hp) was added in 1869. In 1920 two further turbines were installed to provide electrical power for the site, one of 12hp and one of 49hp, and a further installation was made in 1927 of a Gilkes, generating 120hp. This outlasted the iron production and continued to provide electrical power for the National Grid until it was eventually closed in 1999, prompted by the construction of an adjacent new hydro-electric installation.

The fabric survey identified five extant phases of construction. The original phase was the possibly the original bloom smithy, and the western wall of the western ground floor room is the only extant element of this. This incorporates a mounting block, possibly for an axle, suggesting that there was a former water wheel set into a pit on the western side of this wall. The second phase of construction was the addition of a water wheel housing on the eastern side of the building, where the axle mounts for a water wheel survive. The third phase appears to relate to a change of function of the mill from forge to power house, with the insertion of a succession of water-powered turbines. This entailed the construction of an eastern extension presently occupied by the turbines and power generation equipment. The fourth phase of construction comprises the expansion of the structure to the west and appears to relate to the insertion of a forge into the upper floor of the Pug Mill. The final phase of activity related to the Pug Mill's continued use for power generation through the twentieth century and entailed the expansion of the power facility to accommodate the installation of the large Gilkes turbine in 1927.

The turbine assessment identified the existence of two surviving turbines, the large 1927 120hp turbine within a central penstock pit, and a smaller turbine in the Phase 2 wheel pit. The latter was identified as the 12hp Gordon turbine of 1920. The large 1927 turbine was unusual in that it had a propeller runner, and was the only turbine made by Gilkes to this general specification.

It is recommended that the development and conversion should be allowed to proceed as this will ensure that the building is preserved and will prevent its natural decay; however, the conversion of the building should involve as little intrusive disturbance to the existing fabric as possible. Given the unique character of the large Gilkes turbine it is recommended that this should be preserved *in situ*, and if possible also the mechanical components of power generation.

It is recommended that an instrument survey be undertaken to accurately locate the phasing relationships on the south external elevation and to produce an accurate plan of the features located within the former wheel pit. It is also recommended that detailed elevations be produced of the internal elevations of the western cell of the ground floor (GF1). Any external ground work should also be undertaken under archaeological supervision as it is likely that remains of water courses and possibly earlier structures lay close to the Pug Mill.

ACKNOWLEDGEMENTS

Thanks are due to Simon Drummond Hay of Rural Business Homes Ltd and Paul Duckett of Mason Gillibrand for their assistance in the setting up of the project and for enabling access. We would also like to thank John Hodgson, Lake District National Park Archaeologist, for his assistance in the setting up and monitoring of the project. We would like to thank Eleanor Kingston, Lake District National Park Authority, for providing information from the SMR and to the staff of the Cumbria Record Office (Barrow) for considerable help in the course of the project. We are particularly grateful to Mike Davies-Shiel for invaluable information concerning the pug mill and for additional information concerning the later development of the site.

The documentary study was undertaken by Paul Belford (Senior Archaeologist) and Alex Norman (Archaeology Officer) of Ironbridge Archaeology. The fabric survey was undertaken by Chris Wild and Neil Wearing of OA North, who together wrote the report. The turbine study was by Sam Murphy. The drawings were produced by Chris Wild and Emma Carter. The report was edited by Jamie Quartermaine and Emily Mercer of OA North. The project was managed by Jamie Quartermaine.

1. INTRODUCTION

1.1 CONTRACT BACKGROUND

1.1.1 Oxford Archaeology North (OA North) were commissioned by Mason Gillibrand, on behalf of Rural Business Homes Ltd to undertake a programme of archaeological investigation of the former Pug Mill at the Backbarrow Ironworks (Scheduled Monument 506), Haverthwaite, Cumbria (SD 3555 8470 (Fig.1)), in advance of a proposed commercial development of the site. A feature of this development was the conversion of the former Pug Mill for use as office accommodation.

1.1.2 This building was known to contain one or more water turbines and an electrical power generating plant, which are to be partially removed in the course of conversion. In view of the importance of the works and its status as a Scheduled Monument, English Heritage and the Lake District National Park Authority have required that a study be made of the building and the turbines in order to assess the archaeological importance of the building. The work was undertaken in accordance with a project design by OA North and a brief by John Hodgson, the Lake District National Park Archaeologist. The work involved a desk-based study of the Pug Mill, which followed on from earlier studies of the Backbarrow Iron Works (LUAU 1992; LUAU 1998). A fabric survey of the building intended to assess the archaeological importance of the structure, and an archaeological assessment of the turbines preserved within the Pug Mill.

1.2 BACKGROUND

1.2.1 ***Topographical Background:*** the Backbarrow Ironworks is situated at the south end of the village of Backbarrow, approximately 4km south-west of Newby Bridge. It lies within the South Lakeland District of Cumbria and is within the Lake District National Park, though prior to 1974 it lay within the Lancashire Hundred of Lonsdale (Lancashire North of the Sands). The site extends on both sides of the road through the village and is situated between the Lakeside and Haverthwaite railway to the west and the River Leven to the east. The furnaces are set into the moderate to steep slope of the Leven Valley, and the ancillary buildings and water mill are set on the flat flood plain of the river. Ore, coke and scrap metal store-houses were constructed to the west of the furnace and higher up the slope, thereby using gravity to help with the movement of raw materials. These were directly supplied by the railway which was further east and up-slope of the store houses.

1.2.2 The position of the ironworks, which developed from a bloom forge, reflects the original need for a fast-moving river to provide water power, and from the availability of raw materials in the area. Charcoal was supplied from the

surrounding woodlands and iron ore was mined at Lindal in the Furness peninsula and was shipped around the coast to Haverthwaite.

1.2.3 ***Historical Background to the Backbarrow Ironworks:*** the Backbarrow site represents a small-scale, essentially eighteenth century, ironworks which has been modified throughout its history with the minimum of capital investment. Consequently, it is now the only site in which many technological developments can be studied. It was the second blast furnace to be built in Cumbria, the first being at Cleator Moor (Riden 1987, 29-30; Philips 1977, 26), and the last in Britain to convert to coke-firing. Whilst a number of charcoal-fired blast furnaces survive in Britain, all are essentially eighteenth century in date and embody no nineteenth century developments (Crossley 1980, 3). The nineteenth century form of blast furnace, which differed markedly in its scale, build and site plan, has now totally disappeared. Backbarrow, therefore, is now the only site in Britain in which the development of nineteenth century charcoal-fired blast furnace technology can be demonstrated (Crossley 1980, 4).

1.2.4 ***Pre-1711 Iron-working:*** the earliest documentary reference to iron working at Backbarrow is in 1685 when James Maychell of Haverthwaite took a lease at the site and established a bloom forge, although it is possible that the forge was erected on the site of an earlier bloom smithy (Davies-Shiel pers comm). John Maychell's will, dated 1 November 1702, left his iron forge at Backbarrow to his son John Machell, and in the inventory of the 7 November 1702 he had stock at the forge to the sum of £100 (Lancs RO, WRWF 1702 after Cockerill 1989, 263).

1.2.5 ***The Backbarrow Company 1711-1818:*** in 1711 the Backbarrow Company, consisting of William Rawlinson of Force Forge, John Machell of Backbarrow, Stuart Crossfield of Plumpton, and John Oliphant of Penrith, was formed and in the same year began the erection of a charcoal-fired blast furnace near to the site of the bloom forge (CRO(B) BZ5). The construction of the furnace was contracted to Christopher Burns using masons from Lancaster. The raw materials for the furnace came from as far away as Ireland (cast iron work) and Liverpool (fire-bricks). In the following year the bloom forge (now the Pug Mill) was converted to a finery forge (Fell 1908, 208, CRO BZ185), where the pig iron produced in the furnace could be decarbonised and converted into wrought iron.

1.2.6 The industry proved to be very successful and profitable, in part as a result of political events. Traditionally, the main source of high quality iron had been from Sweden, but from some time prior to 1717 the trade had been interrupted by hostilities between Britain and Sweden causing the cost of Swedish iron to increase from “16 to 24 pounds per ton” (Marshall 1967, 294). The net effect was to increase significantly the demand for Furness iron.

1.2.7 Thirty years after its construction the furnace stack was rebuilt (Davies-Shiel pers comm) and once again in 1770 (Fell 1908, 208). In 1753 an anchor smithy was added, and in the following year a conveyance of land at Backbarrow Furnace (CRO B/2/1754) allowed the company to build one or more dwelling houses,

outhouses and other buildings, which suggests a period of expansion. By 1796 the Backbarrow Ironworks had an annual output of 700 tons (Riden 1987, 29).

1.2.8 ***Harrison Ainslie and Co 1818-1917/8:*** in 1818 the Backbarrow Company was taken over by Harrison Ainslie and Co (formerly the Newland Company) who installed a new blowing machine with cylindrical bellows (Fell 1908, 228). In 1852 the Ironworks was unsuccessfully advertised for sale, when it included a charcoal furnace, refinery and drawing forge with office (Pug Mill), manager's cottage, other cottages, workmens' houses, gardens and land. The advertisement stipulated that the use of charcoal for iron manufacture was not to be continued at the site (CRO BZ87). In the event iron production continued and three years later (1855) a water lift was installed for charging the furnace and a drying shed was erected adjoining the casting shed (Fell 1908, 224, 230).

1.2.9 At some time between 1866 and 1869 the Lakeside and Haverthwaite branch line was built as an addition to the main Furness Railway (Quayle and Jenkins 1977, 9-10), probably incorporating the siding to the ironworks at this time. This led to a significant development to the western side of the site, including the construction of railway sidings for the works.

1.2.10 In 1870 the furnace was again rebuilt, as demonstrated by a dated lintel and at some time after 1888 (OS First Edition 1:2500 map) a new water-wheel was installed.

1.2.11 ***Charcoal Iron Company to 1964:*** in 1917/18 Harrison Ainslie and Co became the Charcoal Iron Company, subsequently to be taken over by David Caid Ltd. This precipitated considerable changes to the works in 1921. The furnace was converted to coke from charcoal and this involved the rebuilding of the stack, and the installation of a steam engine for blowing air into the hearth. The casting hall was replaced and a system to use waste gases was installed.

1.2.12 At some time prior to 1936, the turnpike road through the site was improved. This caused some modification to the site and led to the erection of a new water lift and bridge for charging the furnace. In the 1950s a coke-fired cupola furnace was installed to recycle scrap metal. However, in 1963 the furnace was extinguished for the last time due to a dramatic fall in the world iron price. The fate of the company was withheld from its customers, however, to allow the substantial stocks of iron to be sold on. The company folded in 1964 and much of the equipment was dismantled and sold for scrap (Davies-Shiel pers comm), although remarkably the steam engine was left *in situ*.

1.3 PREVIOUS WORK

1.3.1 In the latter part of the 1970s interest in the preservation and development of the site was encouraged by Cumbria County Council, Lake District National Park Authority and the centre for North West Regional Studies at the University of Lancaster. In 1976 a survey and discussion paper was produced by the Director of Planning, Cumbria County Council, and the Lake District National Park Officer.

In addition, the Northern Mill Engine Society produced a report on the condition of the blowing engine. Further to this interest Dr David Crossley undertook a rapid survey of the structural condition of the monument in 1980. The survey, which included a photographic record, addressed the prioritisation of conservation measures and also paid particular attention to the storage sheds on the west side of the site which had been largely overlooked by previous surveys.

1.3.2 Subsequent to the 1980 report little archaeological work was undertaken until an archaeological investigation in 1992 by the Lancaster University Archaeological Unit (now OA North) (LUAU 1992). This programme of work involved an assessment of the ironworks in conjunction with a fabric survey of the furnace area, including elevation drawings of the furnace and roaster house. This was followed by a programme of survey by the RCHM(E) (report pending) which generated a ground plan of the whole site in conjunction with an oblique photographic survey of all the buildings.

1.3.3 An archaeological evaluation and assessment was undertaken by LUAU in 1998 in order to inform an earlier proposal for the development of the Backbarrow site (LUAU 1998). In the event the development did not proceed. This phase of work entailed further documentary work and a programme of trial trenching across the extent of the site, but in particular revealed the twentieth century casting sheds to the south-east of the blast furnace. In February 2000 an inventory was made of the more significant artefacts held within the Pug Mill (LUAU 2000).

2. METHODOLOGY

2.1 PROJECT DESIGN

2.1.1 A project design (*Appendix 2*) was submitted by OA North in response to a request from Rural Business Homes Ltd for an assessment and fabric survey of the Pug Mill, Backbarrow. It was designed in accordance with a project brief (*Appendix 1*) by the Lake District National Park Archaeologist.

2.1.2 The project design provided for a desk-top survey, a fabric survey of the Pug Mill by enhancement of architects drawings, and an appraisal of the extant turbines. The work has been carried out in accordance with the project design. The results of the assessment, fabric survey and study of the turbines are presented within the present report.

2.2 DESK-TOP SURVEY

2.2.1 The desk-top survey examined sources obtained as part of earlier studies (LUAU 1998; Trueman 1991) and also re-examined primary sources in order to establish the history of the Pug Mill site. The primary sources were the Cumbria Record Office (Barrow) and the Lancashire Record Office (Preston). The earliest map identified of Backbarrow was from 1808 (BDB H5/map 9 1808) showing the property of John Birch and Robt Robinson and depicts a building on the site of the present day pug mill. Mike Davies-Shiel was consulted and provided considerable help with the study, and also a set of photographs, mainly from the mid twentieth century. An invaluable set of photographs has also been provided by Ron Mein, mainly from the last days of operation.

2.3 FABRIC SURVEY

2.3.1 A fabric survey was undertaken of the Pug Mill and was intended to provide a record of the structure prior to any intervention, and to enable a programme of analysis to assess the development of the structure.

2.3.2 ***Site Drawings:*** plans and elevations were previously produced for the building by the architects (Mason Gillibrand), and these were augmented by additional survey and corrected where appropriate. The existing drawings were enhanced to show important architectural detail and provide the basis for fabric analysis. The fabric recording was undertaken by manual survey onto paper copies of the architects drawings, the alterations were then incorporated into a CAD system to produce the final drawings. The drawings were produced at a scale of 1:50 in elevation and 1:100 in plan. The survey produced the following:

Ground and First Floor Plans

East, north, west and south external elevations

2.3.3 ***Photographic Archive:*** a photographic archive was produced utilising a 35mm camera to produce both black and white contact prints and colour slides and digital photographs were also taken. The archive comprised general shots of the buildings (both internal and external) and their surroundings and detailed coverage of architectural features.

2.3.4 ***Interpretation and Analysis:*** a visual inspection of the building and the surrounding area was undertaken using OA North buildings proforma sheets and an outline description was maintained to RCHM(E) Level II survey. The analysis examined evidence for the 1685 bloomsmithy and the earlier turbines, and the results are presented in *Section 4.*

2.4 TURBINE SURVEY

2.4.1 A survey was undertaken of the extant turbines and power generation equipment, which entailed both documentary studies and also a detailed investigation of the surviving remains; the survey was undertaken by a specialist, Sam Murphy. The documentary survey entailed consultation of the original records for the turbines held by Gilbert, Gilkes and Gordon Ltd of Kendal. It was fortunate that in the course of the site investigation a copy of the blue prints for the Gilkes turbine was discovered. The document has been copied and is reproduced in this report, the original will be passed to the Cumbria Record Office at Barrow.

2.4.2 The site investigation entailed the production of a detailed photographic record, and the production of a gazetteer of the principal components. The latter has been linked into the present descriptive report for the turbine and power generations gear.

2.5 ARCHIVE

2.5.1 The results of the work programme formed the basis of a full archive to professional standards, in accordance with current English Heritage (1991) guidelines. This archive is provided in the English Heritage Centre for Archaeology format, as a printed document, and will be submitted to the Cumbria Record Office (Carlisle). A synthesis (the evaluation report and index of the archive) will be submitted to the Cumbria Sites and Monuments Record and the National Monuments Record.

3. DOCUMENTARY STUDY OF THE PUG MILL

3.1 SUMMARY OF THE DOCUMENTARY STUDY

3.1.1 There is little in the way of documentary evidence for the development of the Pug Mill site. In its present form, it only appears on maps from the second half of the nineteenth century, although there is a crudely depicted structure in the vicinity of the Pug Mill on an estate map of 1808 (CRO(B) BD/HJ/(Fig 3)). Its location on the site suggests that it may be on the site of an earlier water-powered structure, as it is situated at the end of the tail race leading from the River Leven, and incorporates a fall of *c*3m, and was probably the site of one or more of the several forges documented during the life of the Backbarrow ironworks complex (Bowden 2000, 68-70). The present documentary research has not, however, been able to confirm this with certainty.

3.2 FORGES AT BACKBARROW

3.2.1 One of the three Furness bloom smithies in operation in the mid-sixteenth century was located at Backbarrow, but the exact location is not certain (Fell 1908, 178-90). In 1695 John Machell built a weir across the River Leven to power a bloom forge (Bowden 2000, 68). This corresponds with the higher weir at Backbarrow, which is the only one shown on the earliest map, the 1808 estate map (CRO(B) BD/HJ/(Fig 3)). Following the erection of the blast furnace at Backbarrow in 1711 a finery forge was established in the following year, which probably represented the conversion of an existing bloom forge on the site (Fell 1908, 208; Bowden 2000, 7-10). There were at least two, and possibly three forges on the Backbarrow site in the eighteenth century. However, there is some confusion as the company owned several forges elsewhere, and there is no direct documentary reference to the location of the Backbarrow forges. There is, however, mention of the forges in internal company documentation, particularly during the introduction of blowing cylinders in the 1730s. The first pair of blowing cylinders appears to have been made in 1736-7 to replace traditional leather bellows. In 1738 another pair 'of cylindrical Bellows, & Appurtenances' was supplied to the Forge, and in 1739 a third set of blowing cylinders was erected, this time in the chafery (Cranstone 1991, 88). This suggests that three forges were in use at this time on the Backbarrow site. The finery and chafery forges were still in use, with their iron blowing cylinders, in the 1770s (Fell 1908, 250). During the period 1753 to 1773 there was also an anchor smithy (Fell 1908, 253).

3.2.2 It would appear that in the eighteenth century there was a foundry, separate from the main furnace in addition to the finery and chafery forges (Fell 1908, 238-40; Mike Davies-Shiel, pers comm). Certainly two of these forges continued in operation into the nineteenth century. In 1852 the works was offered for sale, and was described thus: '*The property on the west side of the river consists of Charcoal Furnace, Refinery and Drawing Forge, with Office*, [Pug Mill]

Manager's Cottage, other Cottages, Workmen's Houses, Gardens and Land...' (CRO(B) BZ87). Sometime shortly after this the forging of bar iron at Backbarrow appears to have ceased, despite the apparently widely-held opinion that '*there never was, nor ever will be, an iron to equal it in quality and general usefulness*' (Fell 1908, 255).

3.3 THE PUG MILL BUILDING

3.3.1 All of the evidence for the present building comes from nineteenth and twentieth century map and photographic evidence. A building is shown on, or near to, the location of the present Pug Mill on an estate map drawn in 1808 (CRO(B) BD/HJ (Fig 3)); this shows a rectangular building, the extent of which appears to be confined within the footprint of the present structure, and a mill race is shown entering the site from above the weir to the north. There is, however, some doubt as to the accuracy of this particular map; its main focus is the Backbarrow Mills and estate to the north and not the ironworks site as such, and there are inconsistencies of scale, proportion and alignment with later maps that cannot all be reconciled with topographical changes.

3.3.2 The 1848 First Edition Ordnance Survey plan (Fig 4) depicts a rectangular building with two slight protrusions, on the north and east sides, which is clearly on the footprint of the present structure; there is, however, no indication of the mill race or pond to the north. The western wall of this building is in alignment with the west wall of the present structure; immediately to the east is a second weir across the river, and to the south (on the river bank) is a similarly-shaped building. It has been suggested (Bowden 2000, 68) that, if the Pug Mill building was a forge, then the second building was also a forge. Certainly both structures (as depicted on the 1848 map) are very similar in plan. It is possible that the new weir supplied a headrace (not shown on the map), and that the headrace may follow the alignment of the present Pug Mill tail race.

3.3.3 A map of *c*1870 (Fig 4), again drawn to show the Backbarrow Mill and Estate (CRO Barrow BD/HJ 320), depicts the two buildings as shown on the 1848 map with little change. The lower weir is not shown, although indentations in both sides of the riverbank opposite the downstream building suggest its location. By this stage it is clear from other evidence that forging had ceased at Backbarrow (Fell 1908, 255). By 1866 the Pug Mill had a 8.5hp water turbine installed to replace a water wheel, and another turbine (of 40hp) was added in 1869 (Mike Davies-Shiel, pers comm). These additions appear to have caused some modifications to be made to the water supply system, and it was at this time that part of the building was converted to a Pug Mill, for the manufacture of furnace plugs and other clay products for the use of the ironworks (Mike Davies-Shiel, pers comm).

3.3.4 By 1888, when the First Edition 25" Ordnance Survey map (Fig 4) was produced, the downstream building had been demolished, and the present Pug Mill building had been extended to the east, forming its present footprint. This probably reflects

the changes made in the late 1860s to accommodate the turbine installations, and which were not shown on the 1870 sale plan. Two linear structures (stables) had been erected to the south of the Pug Mill.

3.3.5 The 1911 Ordnance Survey plan shows little change to the outline of the Pug Mill building, although one of the stables to the south had been demolished. This corresponds with a photograph of *c*1900 (Rushton and Snell 1983, 74), which shows the Pug Mill with its eastward extension and the single linear building to the south; a slightly later photograph, *c*1910 (CRO Barrow BDP 68/3) shows the same arrangement. Neither of these photographs are sufficiently clear to give any indication of the presence or absence of the tail race. At some point between the wars the casting shed, adjacent to the furnace, was rebuilt and this alteration is shown on the 1938 Ordnance Survey plan (Fig 7) and on a photograph (CRO BDP 68/4). No external changes are evident to the Pug Mill in the photographs or on the maps.

3.3.6 The 1938 map (Fig 7) does, however, depict for the first time a tail race emerging from the Pug Mill building and returning to the river, which suggests that the previous tail race was culverted or indeed non-existent. This is an important addition, for during the inter-war period a new turbine installation was installed to provide the ironworks site with its own electricity supply (LUAU 1992, 23). Two turbines were ordered in 1920 from the Gordon Turbine Company, one of 12hp and one of 49hp (Mike Davies-Shiel, pers comm), and a further installation was made in 1927 of a Gilkes 33 Inch Series Y turbine, generating 120hp (Mike Davies-Shiel, pers comm). The blueprint for this (shown in Figs 8 and 9), together with operating instructions for the governor, were discovered on site on 4th December 2002 (presently retained by OA North).

3.3.7 The installation of these turbines required significant alteration to the eastern side of the Pug Mill structure, and are shown on a map of 1956, prepared for the Charcoal Iron Company (Mike Davies-Shiel, pers comm). Following the demise of the ironworks, the turbines were used to supply power to the National Grid. A logbook recovered from the site on 4th December 2002 (currently retained by Ironbridge Archaeology) records the day-to-day working of the turbine room from 1957 to its closure in 1999, when a new turbine installation was built to the north of the Pug Mill building. This caused some modifications to be made to the original water intake to the Pug Mill, including blocking off the main entry supply and partially infilling the northern end of the headrace.

4. FABRIC SURVEY

4.1 GENERAL DESCRIPTION

4.1.1 The Pug Mill is currently used for light industrial storage, and was until recently (1999) a hydro-electric power house. It comprises a two-storey structure with a landing between the upper floor and the two elements of the ground floor. It is set into the slope on the western side allowing access to the upper and lower floors from the raised ground level. The build is of local rubble stone (limestone and slate), which is roughly faced and coursed, bonded with recessed mortar externally. The majority of the interior is heavily limewashed, with several areas of cement rendering. The roof is slate with internal lime torching on the eastern pitch and slate over felt on the western pitch.

4.1.2 At the north end of the site, a weir on the River Leven diverts water into a large holding pond. The downstream end of the pond is now occupied by a forebay with filter screens and intake gates which provides water to a small, very recent, hydroelectric power station just to the north of the Pug Mill. Some remains of the earlier mill-race from the pond were observed beneath vegetation and debris to the immediate north of the Pug Mill. A tail race extending out from the south-east corner of the structure also survives (Fig 2).

4.2 BUILDING PHASING

4.2.1 The building description tallies with the two plans of the Pug Mill. For descriptive purposes the building has been divided into ground floor (GF) and Upper Floor (UF). Within each floor there are a series of 'rooms', hence GF4 (for example) is Room 4 on the Ground Floor. Within each of the rooms are segments of wall, or structural features which are allocated lower case letters, and hence GF1e, refers to wall stub (e) in Room 1, on the Ground Floor.

4.2.2 ***Phase 1:*** the survey recorded five structural phases to the surviving Pug Mill. The earliest fabric was located in the interior of the structure and has been heavily truncated; the majority of its survival was within the western cell of the ground floor (GF1) (Fig 10). It appears to represent the remains of a rectangular structure, of similar dimensions to that shown on the Backbarrow Estate Map of 1808 (CRO BD/HJ/Plan 9 (Fig 3)); this would appear to have been the Backbarrow Company's finery forge, which itself was adapted from the bloom forge in *c*1712. As this represents the earliest surviving fabric on the site, there is the possibility that this incorporates fabric from the original bloom forge.

4.2.3 The western wall of the ground floor (GF1d) has the best survival of this phase (Plate 2), but has largely been obscured by limewash internally, and earth retaining on the external face. It is 15.35m in length and appears to have been bonded with a lime mortar containing large pebble inclusions. The wall has a partially-quoined return at its southern end, 2.5m in length, which included a reused sandstone

block. This southern return of the wall (GF1c) was rebuilt east of the western jamb of the present wagon-door. The external face of the southern return suggests that the structure was two-storey, but with a slightly lower roof-line than the present structure. The upper part of wall GF1d was remodelled in Phase *4 (Section 4.2.14*), however, two piers project above GF1d into the first floor, and have been incorporated into the later structure, and appear to form part of the western wall of the original two-storey structure.

4.2.4 Two large sandstone blocks (Fig 10), each *c* 0.6m x 0.6m, located towards the southern end of the western wall (GF1d), each 0.2m above present ground level, have been roughly cut flush with the wall face; these probably represent the mounting for a large mechanical component. The Backbarrow estate map of 1877 (CRO BD/HJ 320 (Fig 5)) shows a leat extending to and no further than this point on the northern side of the earlier phase of the pug mill, and there is the possibility that these blocks were the axle mounting for an external overshot water wheel. Their probable original extension within the structure may however suggest that they formed the base of an internal machine, possibly a forge hammer, and were cut back to the wall when the function of the building changed.

4.2.5 The eastern wall (GF1a/j) of ground floor room GF1 (Fig 10) is of similar construction and thickness to that on the west (GF1d), but has no stratigraphic relationship with it as the southern wall, GF1b, abuts both the eastern wall (GF1a) and the western wall (GF1d) (which includes the narrow westernmost part of the south wall). The eastern wall (GF1a/j) is of reduced thickness above 1.75m above ground level, similar to the eastern external elevation of the present structure (GF4b), and this remodelling/rebuilding appears to have been contemporary with the infilling of the southern elevation.

4.2.6 The western part of the northern wall (GF1e, (Fig 10)) at ground floor level appears contiguous with the western wall, and is a substantial wall, over 3m high, with buttresses. This probably represents the original dam wall and is consistent with the use of this part of the building as a forge.

4.2.7 ***Phase 2:*** the second phase of construction comprises the extension of the structure to the north and south-east, which appears to be shown on the Ordnance Survey map of 1848 (Fig 4). It would also appear, from the stratigraphic relationships, that a water wheel was added to the southern end of the external eastern elevation (GF41a and GF41b) at this time (Fig 10).

4.2.8 The Phase 2 northern extension was evident in the north-eastern corner of the western cell of the ground floor, and is of similar construction to the western wall, comprising an east/west aligned buttressed wall (GF1g) with a return to the north (GF1f) at its western end. It also appears to have a return to the south (GF1h) on the same alignment as the eastern wall of the cell, but this has been obscured by a later Phase 5 staircase (*Section 4.2.15*). It is probable that this wall related to a secondary phase of construction, but may also incorporate elements of the original Phase 1 structure.

4.2.9 The only evidence of the extension at the south-eastern corner of the building is the exposed southern end of the eastern wall (GF1a) of ground floor room (GF1) (Fig 10). This has been remodelled to form a flush end to the wall level with the face of the south elevation, using both stone and brick. This suggests that it had previously continued to the south, potentially as part of an earlier extension.

4.2.10 An arch in the eastern elevation (GF4b) of the wheel pit (room GF4), has a large sandstone base with an extant mounting bolt; a corresponding arch is cut into the Phase 1 wall (GF1a) forming the western side of the wheel pit and has a similar sandstone base. These are diametrically opposite each other and were almost certainly axle supports for a water wheel. They are 3.95m apart and would indicate that the wheel was potentially 3.6m in width, which is considered large for a nineteenth century water wheel. However, undershot wheels, which are less efficient than overshot wheels, are often of a substantial size in order to provide sufficient power from a relatively low head of water (S Murphy pers comm). The blockwork visible beneath the water in the centre of the wheel pit (GF4d) is in its present form clearly a support for the later turbines (Phase 3), but may also represent the modification of an earlier central pillar, possibly supporting two narrower water wheels. The northern extent of this wheel pit has been truncated by the concrete wall (GF4c) for the turbine installation of 1927 (Phase 4). There is a small rectangular extension to the south-east corner of the building as shown on the OS First Edition map of 1888 (Fig 6), which may potentially have housed this water wheel. Alternatively, the wheel may not have been roofed at this stage. There is no physical relationship between these features and the western and northern walls noted above: Consequently, it is not possible to state definitively whether this wheel pit is later than, or contemporary with the Phase 2 features.

4.2.11 ***Phase 3 (1867-1927):*** the third phase of activity comprises the widening of the structure on its eastern side up to the river edge, and appears to date between the Backbarrow Estate Map of *c*1877 (Fig 5) (CRO BD/HJ/320), where the structure is shown in its Phase 2 plan, and the First Edition 25" to 1 mile Ordnance Survey map (Fig 6), where it is shown in its present plan. The date of the estate map (CRO BD/HJ/320) is doubtful, but must post-date the construction of the Furness Railway in 1866-69.

4.2.12 The eastern wall (GF4b) of this extension (GF4) belongs to this phase, with some remodelling of the western wall of the earlier wheel pit structure, which is wider at the base and has been increased in height above the original wall-plates, observed on the western face at first floor level. This suggests that, not only was the remodelled structure wider, but that it was also raised.

4.2.13 The remodelling for this phase relates to the conversion of the building for power generation and the establishment of turbines in the eastern extension; the earliest of which dates from 1866. By 1888 (OS First Edition 1:2500 map) (Fig 6) the mill-pond to the north had been expanded up to the road, providing a reservoir of water for the furnace water wheel and for the turbines, a sluice gate and modified dam wall are also shown. The tail race to the south of the Pug Mill is not shown on the Ordnance Survey mapping until 1938, although the earlier maps (1888) do

show a spur in the western bank of the river at its point of outflow, and it would appear to be of contemporary build to the eastern elevation of the Phase 3 extension. It may therefore have been culverted. A sub-rectangular aperture, 0.35m wide in the eastern wall of GF4, probably relates to an early turbine.

4.2.14 ***Phase 4:*** the fourth phase of activity observed relates to a further extension of the structure prior to 1888 (OS First Edition 1:2500 map) and comprised the addition of an outshut on the western side. This was of similar stone construction to earlier remodelling and included the rebuilding of the northern wall to the west of the Phase 3 extension. The new outshut is of single storey construction, and is terraced into the hillside to the west, but would appear to overlie a leat shown on the 1877 Estate Map (CRO BD/HJ/320). This extension of the building required a further change in roof height to incorporate the extended pitch. This alteration comprised brick piers above the western walls and the insertion of new king post timber trusses. A separate room (UF1) was also created with the insertion of a timber stud partition covered in metal sheeting on the external (UF2) faces (Fig 11). A half-loft in the eastern part of this new room was supported on a large scantling arcade plate. New floor joists of similar size were also inserted at this time. A small forge located in the south-western corner of the new room (within the outshut UF1) probably relates to this phase and would explain why the area was partitioned and screened with metal sheeting.

4.2.15 ***Phase 5 (1927-1999):*** the fifth phase of activity relates to twentieth century activity and was associated with power production from the Pug Mill. The mill-race which entered the north-eastern corner of the building was blocked and the water was then piped to the turbines; evidence of the piping for two turbines survives *in-situ*. The north-eastern room of the ground floor (GF2) appears to have been remodelled early in the twentieth century to form a generator room, although any internal relationships with the earlier structure are concealed beneath concrete render. The last turbine, installed in 1927, included the insertion of a large concrete block-built water turbine pit (GF3 (Fig 10)), located centrally within the eastern elevation and which was cut into much of the earlier fabric. It also comprised a staircase with landing allowing access to both eastern and western cells of the ground floor.

4.2.16 The south-western room at first floor level (UF1 (Fig 11)) was remodelled at this time with the insertion of an entrance in the eastern wall and the addition of shelving containing spare parts for the generating machinery. Many of these parts, together with their associated documentation and packaging, survive *in situ*. The ground floor rooms appear to have been used as storage. Rails set into the concrete floor (GF1 (Fig 10)) may belong to Phase 3 or 4 (and therefore relate to an earlier industrial use of this part of the building) but were retained for use in Phase 5. Of interest is a substantial collection of wooden foundry patterns, including patterns for pipes, wheels and other objects. There are also three tuyeres from the blast furnace, together with assorted machinery parts.

5. THE PUG MILL TURBINES AN ASSESSMENT OF THEIR HISTORICAL SIGNIFICANCE

5.1 INTRODUCTION

5.1.1 ***Waterpower:*** throughout most of the period of operation, waterwheels provided the motive power to operate the bellows (and later the blowing cylinders) of the furnaces, and the bellows and hammers of the fining forges (the latter used to convert brittle pig iron into malleable wrought iron). The head of water or 'fall' available at Backbarrow was stated to be 18ft (5.53m) in a description of 1852 (CRO/BZ87), with the greatest part due to the steep slope of the river bed just above the Pug Mill.

5.1.2 Little is known about the early use of waterpower, but it is probable that the seventeenth century bloom forge was located close to the river bank, and at least three forges (two finery and one chafery) were at work at Backbarrow during most of the eighteenth century. They were equipped with cylindrical cast iron bellows in 1737-9 and some of these forges continued in use until the middle of the nineteenth century (Cranstone 1991, 88-90). Their positions are unknown, but probably one at least was on the site of the Pug Mill/turbine house, and another may have been located in a building just to the south (Bowden 2000, 68-9).

5.1.3 The blast furnace, situated at the foot of the west slope of the fell and well away from the river, had an overshot waterwheel close to the furnace stack to drive the furnace bellows. This wheel would have been supplied with water carried forward from the weir in a high-level water race supported on wooden trestles, an underground tail race carrying the water from the base of the wheel back to the river; the river end of this race is shown on early OS maps. In 1818 the leather bellows used for the air blast were replaced by a new blowing machine which utilised cylindrical bellows, and some time after 1888 the water wheel was replaced with another. Water power for the furnace blast was abandoned in the 1921 when the conversion to coke firing and a hot-air blast system took place, and a steam engine was installed for that more onerous duty.

5.1.4 ***Water Turbines:*** water turbines became widely available as an alternative to the simple waterwheel in the mid nineteenth century. These are very compact and more efficient than the overshot wheel, and, in the case of high-power requirements, were less expensive, but they required a much higher degree of engineering skill in their design and construction. There are many different types, but only two classes: the impulse and reaction turbines:

5.1.5 ***Impulse Turbines:*** impulse turbines typically have one or more jets which direct water onto a revolving wheel in an air-filled environment, and include the *Girard* (inward or outward flow), and *Pelton* (inward flow). In Britain an impulse turbine whose jet impinged on a vaned runner wheel was invented by Cumbria manufacturer Gilbert Gilkes and Co in 1924, and is still in current production as the *Turgo-Impulse* model.

5.1.6 ***Reaction Turbines:*** reaction turbines have a wheel running in a water-pressurised casing, and examples are the radial outward flow *Fourneyron*, radial inward flow *Francis* and axial flow *Jonval*. In Britain, and particularly in Cumbria, the radial-flow *Vortex* with single or double axial discharge was an alternative to the *Francis* machines. This was invented by James Thompson of Belfast in 1850, and adopted by the Williamson Bros of Stainton near Kendal, who commenced the manufacture of these turbines after their move to Kendal in 1856. Their successors from 1881, Gilbert Gilkes and Co, later Gilbert Gilkes and Gordon Ltd, continued production until early in the twentieth century, mostly for low-head applications (that is where the height of the water source was only a little higher than the turbine).

5.1.7 The most common types manufactured in the late nineteenth and early twentieth centuries were Francis-type radial inward flow machines with axial discharge. Large numbers were made with a modified geometry where the Francis runner was changed to produce part-axial, part-radial flow of water, and these *Mixed-Flow* turbines were widely used for large and small applications. Very large turbines of this type were soon being made, particularly in the USA, that could only run at inconveniently low speeds. However another solution, which could double the speed for a given installation, was the adoption of the *Propeller* runner, similar to a ship's propeller. This was used for large and small turbines where higher shaft speeds were needed, at a cost of reduced efficiency under part-load conditions. Ultimately the efficiency problem was addressed by using movable blades on the propeller runner, whose angle could be adjusted to optimise efficiency under reduced heads, thus producing the *Kaplan* turbine.

5.2 THE PUG MILL TURBINES

5.2.1 ***Previous Water Power Configuration:*** the eastern extension of the building (Phase 3) covers the north end of a wide tail race and its eastern wall, 0.77m thick, runs along the river bank. It is open to the south at ground floor level, with a decayed timber wall and the remains of a wooden floor at first floor level (fig 10). Large freestone blocks set into the walls on opposite sides of the tail race channel (GF4), each with a brick-arched aperture above, are bearing supports and show the former existence of a waterwheel here. The eastern extension was thus built as a waterwheel pit forming the upper end of the tail race. Each aperture is 1.0m high and the distance to the water level is 1.95m from the upper surface of the stone, so assuming the axle axis was 0.3m above the bearing support stone, and the tail race water level is unchanged, a waterwheel of *c*2.25m in diameter could have been installed. The distance from the probable position of the wheel axis to the south end of the riverside wall is 2.6m, so a wheel of the suggested size would have been entirely enclosed within the eastern extension building. The space between the wheel pit walls is 3.95m, so the wheel pit could have accommodated a wheel of *c*3.6m wide, with its drive shaft taken west into the mill building proper (GF1), where the pug milling operations took place.

5.2.3 ***Turbine Installations:*** within the present installation are two turbines, one in the central part of the eastern extension of the building, and the other mounted externally on a plinth set in the back of the former wheel pit (GF4) at the head of the tail race. A description of the two installations follows:

5.2.4 ***Large Turbine:*** a concrete-lined rectangular penstock pit (GF3) (5.98m x 2.48m) is set in the middle of the eastern extension of the building (Fig 10), slightly truncating the northern wall of the former wheel pit (GF4) and extending from the riverside west into the main building. This deep, cement rendered pit is a water turbine pressure penstock, and extends vertically from about 0.6m above the upper floor level to substantially below the ground floor level, a total depth of 5.1m. On the river side of this pit the wall height is reduced by 0.69m to form an overflow exit to the river, which would limit the head within the penstock to a maximum of 4.47m if filled completely.

5.2.5 Water had formerly been brought into the penstock from the north via a large circular hole, *c*1.65m in diameter, starting 0.82m above the bottom of the pit in the western extremity of the north wall. The opening is slightly flared to direct incoming water to the east, and the inside wall of the tunnel is a straight iron or steel pipe made of riveted plates, the inner end of which is sealed with concrete at a distance of 6.6m from the pit. In use, the pressure penstock pit would have been filled with water to the available head height, but when inspected it was almost dry, a trickle of water from the inlet pipe draining away through a hole in the south-east corner of the pit via an externally mounted valve.

5.2.6 At a higher level, mounted in the middle of the north wall, a large horizontal-axis water turbine had been installed. From its external appearance this turbine was apparently a conventional open-inlet Francis type machine, designed for submerged use, with radial inward flow and axial outlet via a horizontal large-diameter tapered pipe which carried water through the south wall of the penstock and into the tail race area. A short vertical pillar supports the outer end of the cast iron turbine housing, and a small diameter metal tube from the wall to the housing is for supplying lubricant to the outer bearing of the turbine. A circular inspection plate is fastened to the top of the fabricated steel outlet pipe through which access is made to the turbine runner. This is a typical low-head mill installation where the turbine is fixed to the penstock wall with crown plate, controls and drive shaft in a separate room on the other side of the wall.

5.2.7 The power of the turbine was controlled by altering the flow of water through gaps between adjustable cast iron guide vanes which allow water to pass into the turbine. These are equally spaced around the periphery of the water intake section and were operated by the slight rotation of an annular ring mounted on the turbines base ring, which is itself fixed rigidly into the penstock wall. Control shafts pass through the wall at the top and bottom of the turbine case and rotate the annular ring via short links. The guide vanes themselves pivot about bolts passing through them (not visible unless the turbine is dismantled) between the base ring and the turbine blade housing, and have short links which are connected to the annular ring. The geometry is such that a small angular movement of the

ring pivots the guide vanes about their rotation axis, increasing or narrowing the gap between the adjacent vanes and thus controlling water flow through the turbine.

5.2.8 The interior of the turbine was examined by introducing a small digital camera through the narrow gap between the guide vanes and taking several photographs. It was found that there was no Francis runner immediately under the guide vanes as expected, and the space was empty apart from the drive shaft and a propeller-type runner located in the next housing downstream.

5.2.9 A 0.50m diameter cast iron spigot-and-socket pipe passed through the penstock pit above and to the west of the turbine axis, angled slightly to the east at the south end (*Section 5.2.21*).

5.2.10 ***Power Station Room:*** to the north of the pressure penstock, but entirely within the eastern extension to the building is the power station room (GF2). This has a west wall (GF2c) 4.48m long and a south wall (GF2b) 3.9m long. The north wall (GF2d) is parallel to the south wall for 2.5m but then meets an angled north-east wall which joins it to the east wall (GF2a). This east wall has a large window which is the only source of natural light in the room. The staircase down into this room passes over the drive-train of the electrical generator, and a 0.50m diameter cast iron pipe, which is the continuation to the north of the cast iron pipe seen in the adjacent pressure penstock pit. Near the south-east corner of the room, to the south of the stairway, is a turbine governor, and close to the north-east wall is a steel cabinet containing the electrical generator controls.

5.2.11 Overhead, and lying over the axis of the power train, a large steel girder carries a moveable 2-ton-rated hand winch with chains and hook, and another girder near the north end of the room extends east/west across the room and over the riverside wall. The first of these was evidently used for installation and/or dismantling of the heavy parts of the drive-train; the function of the latter is uncertain.

5.2.12 The south wall (GF2b) of this room forms part of the north wall of the penstock, and set into this south wall at its western end, in a 3.0m diameter by 0.76m deep recess, is the wall plate of the water turbine with its drive shaft. The drive-train from the wall plate comprises a double pulley for the belt drives to the governor, a cast iron bearing support pedestal, a flywheel, a two-shaft David Brown gearbox and an AEI alternator. Modern electrical control equipment is housed in a white cabinet set at the north-west end of the power train. All this equipment appears to be in good condition, and the flexible couplings at each end of the pulley have been only recently renewed. The total length of the drive-train from the turbine wall-plate to the far end of the alternator is 4.75m, leaving a gap of 0.6m to the north wall through which access was gained to the drive-train along the west wall.

5.2.13 ***Turbine:*** the wall plate, painted green, is bolted to the crown ring (seen from the other side of the wall), and both seals the power station from the water pressure in the turbine and supports the drive shaft which is carried through pressure-tight packings to the generating plant. The lower part of the casting carries the serial number 3386. Set into the wall at the top and bottom of the turbine wall plate are

the guide vane control shafts, operated by a system of rods and levers from the governor, all painted grey.

5.2.14 ***Governor:*** the governor is a floor-mounted G. Gilkes and Co Ltd, Type C oil-pressure regulator (No 489). The drive shaft from the turbine carries two pulleys with flexible couplings, which carry two belt drives to the governor. One operates the speed-sensitive regulation device, the other drives the powerful oil pump needed to turn the control guide vanes against the force of the water flowing through the turbine; this regulator is a standard fitment on many installations. The regulation is effected by a strong, steel, rocking shaft on the lower case of the governor which is supported on a wall-mounted bracket and rotates two lever arms. Two long rods pivot on these lever arms, one angles up to the top guide vane control shaft, and the other down below floor level to the other, the far ends of these shafts are those observed in the pressure penstock.

5.2.15 ***Bearing Pedestal:*** this is an iron casting which carries the power train-drive shaft bearing, and has the inscription 'Gilbert Gilkes and Co. Kendal England 1927' on the east side of the casting.

5.2.16 ***Flywheel:*** on the other end of the pedestal is a cast steel flywheel, 44in in diameter by 7in wide, with rectangular indentations in its rim. Flywheels are often used in turbine-driven electrical generating plant to minimise changes in shaft speed which may occur when electrical load is switched on or off.

5.2.17 ***Gearbox:*** the gearbox is used to speed up the electrical generator from turbine rotation speed to a higher speed. This David Brown Series N, N.H. 104, two-shaft gearbox (No G250244), has a 150hp rating and gives an output shaft speed of 1532.2rpm on a 4.04:1 ratio, implying a turbine speed of 379rpm. This is an exceptionally high speed for a large diameter, low-fall, high-output Francis turbine and this anomaly triggered the examination of the turbine interior described earlier.

5.2.18 ***Generator:*** a small AEI AC generator lies at the end of the power train and completes the mechanical part of the installation. No indications of its specification could be found, only a lubrication guide on a label, but a later examination of photographs showed a plate on the west side of the generator which was missed under the poor lighting conditions of the first inspection. Both the gearbox and generator are relatively modern, and probably date from the 1950s.

5.2.19 ***Control Cabinet:*** this is a modern control unit for the electricity generator, made by Agrilek Ltd of Dalton in Furness (now at Barrow in Furness). No details are available on its function or specification.

5.2.20 ***Suction Tube:*** the final part of this large turbine installation is a large suction tube found outside the building in the former waterwheel pit (GF4) forming the south end of the eastern Pug Mill building extension. The north end of the wheel pit is now formed by the concrete block wall of the pressure penstock pit, and close to this wall is an irregular construction of dressed limestone blocks, bricks and cast

concrete, the western part of which forms a platform. A large pipe passes through the penstock wall and continues straight for a distance of 1.85m to an obtuse angle elbow section which carries the pipe down, and slightly east, to dip under the surface of the water in the tail race below. This is the continuation of the discharge pipe from the large turbine seen in the penstock, and forms a suction tube for that machine. The pipe and elbow are both fabricated from riveted iron or steel plates.

5.2.21 ***Small Turbine:*** the cast iron spigot-and-socket pipe seen passing through the power station and pressure penstock is the water intake pipe for a smaller turbine set at the back of the former wheel pit. The cast iron pipe turns east immediately after passing through the penstock wall then down through a wooden floor to the turbine below. An aperture in the wooden floor, just to the south of the point where the pipe passes through it, can just be distinguished, and a handrail each side of it suggests that this was once a stairway to the turbine. The turbine was placed on a 0.30m high concrete pad on the east end of the same plinth which supported the discharge pipe of the large turbine. It is close to the north wall of the wheel pit, near the east side, and its axis is aligned east/west. It has no identification number or name, but was probably a Francis-type, with its runner and guide vanes mounted inside a 1.07m diameter cylindrical cast iron enclosure, 0.8m long, with a radial feed to the case from the top and axial discharge to the right (east). A cast iron right-angle bend, with inspection plate at the back, takes the discharged water vertically into a tapered suction tube of riveted plate construction, the lower section of which was once immersed in the tail race water but has now corroded away. Both intake and discharge pipes have the same external diameter of 0.5m.

5.2.22 A small hand wheel, which operates a worm and gear drive, is mounted on a small casting bolted to the end casing near the discharge pipe; this almost certainly operates internal Francis-type guide vanes which regulate the turbine's speed. On the other side of the casing a 0.05m diameter steel drive shaft, protruding from detachable end plate of the turbine at the west end, is supported on a cast iron bearing pillar and carries a drive pulley 0.15m wide and 0.36m in diameter.

6. DISCUSSION

6.1 THE PUG MILL

6.1.1 This assessment has identified a complex multi-phase structure, possibly dating back to the original late seventeenth century bloom forge, and certainly dating to the structure of the early nineteenth century. The Pug Mill may have the earliest extant fabric on site pre-dating the blast furnace, an important structure in the course of the development of the ironworks, and, significantly, was the last building of the ironworks to go out of use in 1999. The building is of considerable importance in terms of the history of the Backbarrow Ironworks, and has the potential to reveal much of the early, pre-blast furnace history of the site.

6.1.2 ***Phase 1:*** the Pug Mill probably occupies the site of the early bloom forge identified by the documentary study, and the fabric survey has revealed that the earliest phase of construction within the present building could relate to this structure, which was converted to a finery forge in 1712. Its survival is mainly limited to the lower ground floor, but the evidence suggests that it was a two-storey structure, enhancing the information gained from the map analysis about the plan form of the building. The earliest map showing the building was the 1808 estate map (CRO BD/HJ/Plan 9), and this depicts, as far as can be ascertained from the imprecise mapping, the layout of the Phase 1 structure. This structure in its most basic form has the potential to date back to the establishment of the finery forge in *c*1712, or to the earlier bloom forge.

6.1.3 Two large sandstone blocks located on the southern end of the western wall, at the present ground floor level seem likely to have been bearing blocks for a water wheel which would have been located outside (ie to the west of) this wall. The northern wall at ground floor level appears to be contiguous with the western wall. This northern wall is fairly substantial with buttresses and it possibly represents the original dam wall.

6.1.4 ***Phase 2:*** the OS 1848 6" to 1 mile map showed a second phase of construction extending the structure to the north and south-east, and this corresponds with extensions observed within the extant fabric. The easterly extension was intended to accommodate a water wheel, and its axle mount survives within the former Phase 1 easterly external wall, and the eastern mount for the wheel was on a shallow platform. The width of this wheel would have been approximately 3m, which is relatively large for a nineteenth century water wheel. The blockwork visible beneath the water in the centre of the wheelpit in its present form is a support for the later turbines, but may also represent the modification of an earlier central pillar that potentially supported two smaller water wheels. The survey revealed that the tail race most probably also dates from this phase, but was not shown until the 1938 OS map and so was probably originally covered. Given that the extension to the building was first shown on the OS First Edition map, it

would appear that this expansion of the forge occurred in the first half of the nineteenth century.

6.1.5 ***Phase 3:*** the third phase of construction appears to relate to a change of function of the mill, from forge to power house, with the insertion of a succession of water-powered turbines. Again, this has been demonstrated by the fabric survey, which has shown the expansion of the eastern extension necessary to accommodate the power generation equipment, and also revealed that the height of the building was increased during this remodelling phase. The Backbarrow estate map of 1877 (CRO BD/HJ/320) shows the Phase 2 layout, whereas the OS First Edition 25" to 1 mile map (1888) shows the Phase 3 layout; evidently this phase was from between these two dates.

6.1.6 ***Phase 4:*** the fourth phase of construction comprises the expansion of the structure to the west and appears to relate to the insertion of a forge into the upper floor of the Pug Mill. This entailed the addition of an outshut to the western side of the building and gave the building its unusual plan form. This layout is also shown on the 1888 OS First Edition 25" map and clearly Phases 3 and 4 were either implemented at the same time, or were within a few years of each other. Other features relating to the early turbine installations include the sluice gate and modified dam wall to the north of the Pug Mill. These were evident on photographs pre-1999, and on map evidence from 1888 onwards. It is possible that the sluice gate originally fed a water wheel and thus pre-dates 1866, the installation of the 8.5hp turbine, but this was not confirmed by documentary research or field evidence.

6.1.7 ***Phase 5:*** the final phase of activity related to the Pug Mill's continued use for power generation through the twentieth century. A well preserved turbine from this phase survives *in situ* (See section 6.1.7), and the structural changes of this phase show the increased use of new building materials, especially concrete. The expansion of the power facility relates to the installation of the large Gilkes turbine in 1927, which is dated by the letter attached to the specification drawings (Figs 8 and 9). The primary element of this phase was the large concrete penstock pit housing the turbine. It would appear that throughout the majority of the final phase the remainder of the building was used for storage. The south-eastern room at first floor level (originally a smithy) was modified at this time with the insertion of shelving containing spare parts for the generating machinery. Many of these parts, together with their associated documentation and packaging, survive *in situ*. The lower floor was used for storing raw materials. A set of tramway tracks, possibly from Phase 4 were used in Phase 5 for the movement of raw materials, and these tracks are certainly shown on the 1938 OS 25" to 1 mile map. However, they are not shown on the earlier editions, which raises the question as to whether this was a cartographic omission or whether the tracks were only put in place between 1911 and 1938.

6.1.8 The term *'pug mill'* relates to the process whereby clay is comminuted and mixed with other ingredients and water to form the refractory material for the blast furnace. It is to be presumed that at some point in its life it was used for this

purpose, and if so is likely to have taken place in the GF1 ground floor room which was used in its later life for storing raw materials, and would have been the most appropriate place for creating refractory clay. There is, however, no extant evidence of clay working within the room and there is, therefore, no indication of which period it was used for the refining of refractory brick.

6.2 WATERPOWER INSTALLATIONS

6.2.1 The history of the Pug Mill building was evidently complicated, but it is clear that prior to the turbine installation a large, probably undershot, waterwheel was installed in the eastern extension to the main building, at the head of the present tail race. This relates to Phase 2 of the building's development and dates to between 1808 and 1848 (*Section 5.1.3*). Neither the OS First Edition 25" to 1 mile (1888) nor the OS Second Edition (1911) maps show the tail race in its present position. Indeed it did not appear until the 1938 edition but it is probable that the tail race was there from at least 1888, and covered for safety, which led to it being ignored by the OS surveyors. The previous water installation had a leat extending along the northern side of the building (BD/HJ/Plan no 9), indicating that the original wheel was on that side of the building.

6.2.2 There is a history of turbine use at Backbarrow Iron Works from 1866, when an 8.5hp Williamson's turbine operating on a 10ft head was purchased, although there is no indication as to where this was installed. Another Williamson's turbine was ordered in 1869, a 40hp machine working on a head of 14.5ft (Mike Davies-Shiel, pers comm). This head figure is significant as it indicated that it was installed somewhere in or close to the Pug Mill building. Both of these turbines were almost certainly Vortex machines, made according to the Thomson patent.

6.2.3 Fifty years later, in 1920, two more turbines were purchased, probably as direct replacements for the previous ones. Both of these were manufactured by James Gordon and Co of London, who made considerable numbers of Francis-type turbines for the home and export markets. The smaller turbine was a 12hp model working on a 14.5ft head and running at 500rpm. The other was a 49hp model for a 9ft head running at 163rpm, both drove electrical generator plants (Mike Davies Shiel pers comm). The last turbine to be installed was that now present in the power station of the Pug Mill. Examination of company records kindly provided by Mr Tony Watson, Technical Director of Gilbert Gilkes and Gordon Ltd, on 26th November 2002, showed that No 3386 was a Francis turbine purchased in 1927, developing 120hp on a 14ft head using 5650 cu.ft/min. of water (Gilbert Gilkes nd (1)).

6.2.4 ***Turbine Identifications:*** the small turbine still in the waterwheel pit had no identification marks, but was almost certainly a Francis-type reaction turbine; the external shape of the casing is very similar to that of a Gordon-manufactured turbine of that type, and the dimensions are close to those of a Type 24/50 made by James Gordon and Co some five years later in 1925 (Gilbert Gilkes nd(2)). The external parts of the guide vane control are apparently identical to that used by

Gordons, but this is of less significance as many other firms used similar arrangements. To test this identification, the power output of the small turbine was estimated from the head available and the measured size of the cast iron intake pipe. The available head at the Pug Mill is difficult to establish exactly without knowing the penstock and tail race levels when the turbines were installed, but if we assume a head of 14.5ft, an efficiency of 75%, an internal pipe diameter of 19in (0.48m) and a flow rate of 4.5ft/sec, the power developed by the turbine would be 10.9bhp. If the flow rate were as high as 6ft/s, the maximum allowed for ordinary installations, the power output would be 14.5bhp. Some turbines reached higher efficiencies than 75%, but if an 80% efficiency were assumed these figures would increase to 11.7bhp (4.5ft/s) and 15.6 bhp (6.0ft/s). These estimations are in line with the stated 12hp of the 1920 Gordon turbine.

6.2.5 What is clearly ruled out is that the present day turbine is the higher output 49hp 1920 model. Carrying out similar calculations: assuming a 9ft head, 75% efficiency and a flow rate of 4.5ft/s, the water flow rate would be 3884cu.ft/min, requiring an internal intake pipe diameter of 1.3m. Thus the small turbine may be identified with confidence as the 12hp turbine manufactured by James Gordon and Co of London, and supplied in 1920. That being the case the small turbine is of general interest only, being a common type probably made in considerable numbers by its manufacturer, several examples of which are to be found in Cumbria.

6.2.6 While conjectural at this stage, it would appear that the original Williamsons turbines of 8.5hp and 40hp were replaced by Gordon turbines of 12hp and 49hp in 1920, either with their locations reversed, or their water supplies modified to give the different heads. The 49hp model was replaced in 1927 by the Gilkes model still *in situ*, and possibly in the same location. It is interesting to note that the south wall of the power station shows clear evidence of an arch in the wall above the turbine, pointing to structural changes in that area.

Number	Year	Type	Output (bhp)	Net Head (ft)	Flow Rate (cu.ft/s)	Speed (rpm)	Specific Speed (Imp)
2994	1922	Vortex	90	13	69.5	290	105.1
3090	1924	Francis	82	15	60	200	61.4
3117	1924	Francis	410	18	83.33	200	63.8
3118	1924	Francis	455	11	160	104	64.6
3152	1924	Francis	100	8	141	88	65.4
3249	1925	Francis	64	12	60.33	181	64.8
3260	1925	Francis	78	20.5	43.33	310	62.8
3307	1926	Francis	75	12.5	68.00	165	60.8
3384	1927	Francis	85	11	87.5	135	62.1
3386	1927	Francis	120	14	94.17	380	153.7
3515	1928	Kaplan	133	20	73.33	500	136.3
3597	1929	Francis	137	8	191.67	82	71.3
3656	1929	Francis	100	13	87.33	154	62.4
3827	1931	Francis	70.5	19	40	316	66.9
3926	1933	Francis	140	20	74.5	246	68.8

4117	1935	Francis	77.5	20	44	192	40.0
4173	1936	Francis	110	18	65.17	197	55.7
4237	1937	Francis	105	12.5	98.33	190	82.8
4256	1937	Francis	90	106	91	145	71.9
4280	1937	Francis	91	7	137.17	77	64.5
4355	1938	Francis	72.4	11	71.67	163	69.2
4410	1939	Francis	102	10.5	103.17	130	69.5
4454	1940	Francis	150	18	89.5	209	69
Average			**98.2**	**13.0**	**55.8**	**193.9**	**70.5**

Table 1: Specification of Gilkes reaction turbines of similar specification to No 3386 (Gilbert Gilkes and Gordon Ltd nd (1))

6.2.7 In contrast, the large turbine in the Backbarrow power station is unusual. Although listed as a commonplace Francis turbine (Gilbert Gilkes nd (1)), the presence of a propeller runner, which is completely different from a Francis runner, shows that this is not an accurate description. However, the same record confirms that the rotation speed is 380rpm, almost exactly that calculated earlier, and highlights another discrepancy in that the specific speed attributed to No 3386 is 153.7 Imperial units, far in excess of what would be expected from a Francis turbine of that date and size. To demonstrate this, the Gilkes turbine list (Gilbert Gilkes nd(1)) was searched for other reaction machines producing similar power outputs on similar heads, within a range of ± 50%, in the period 1920-1940. Three machines stand out from the general run for their very high specific speeds: the 1922 Vortex, which has a special axial-flow runner, the 1927 Backbarrow 'Francis' machine under discussion, and a 1928 Kaplan turbine. Since the average specific speed of the rest of the turbines listed is only 61.8 (Table 1), it is quite evident that No 3386 was not a normal Francis machine when sold, and thus the propeller runner revealed by the recent inspection was fitted as standard in 1927, and was not a later replacement.

6.2.8 Another important fact to arise from this search of the Gilkes' list is that No 3386 was the only turbine made by Gilkes to this general specification, for no other examples of a Francis turbine with very high specific speed were found in the list. Turbine No 3386 thus represents an experiment by Gilkes with the application of propeller technology to this class of high-power, low-head machines, along with No 3515 (which was exported to Kenya) with Kaplan technology. Kaplan turbines also have a propellor runner, but the blade is adjustable. Since Kaplan turbines were technically superior to the propeller type, more were made subsequently, mostly in very small sizes, but Gilkes did not produce another propeller machine, making the Backbarrow turbine unique.

6.2.9 The reason behind the production of this one-off propeller turbine may eventually emerge if Gilkes' company records ever become available for inspection, but an educated guess may be made from a consideration of Gilkes' history. The original company, Williamsons/Gilbert Gilkes and Co, made Vortex reaction turbines

from 1856, but following their purchase of the engineering company of CL Hett of Brigg early in 1895, Hett's designs of mixed-flow Francis-type turbines were adopted by Gilkes, who continued their production as Turgo, Lunesdale and Trent models in different sizes and configurations (Gilbert Gilkes and Co 1911). In January 1928, Gilkes took over the well-established firm of James Gordon and Co of London, and transferred their manufacturing facilities to Kendal. Gordon's had previously made large numbers of Francis-type turbines, in a number of different configurations, and significantly, were involved in propeller turbine technology from about 1915. By 1925 they had enough experience in that technology to offer propeller runners as alternatives to the normal Francis variety in their extensive range of machines (Gilbert Gilkes nd(2)).

6.2.10 Significantly, the large turbine in the Pug Mill was ordered in July 1927, only six months before the Gordon take-over was finalised and possibly when the two companies were in close contact, if not deep in merger negotiations. The question arises as to whether No 3386 was actually a Gordon turbine, made under license, or a Gilkes turbine made to test the value of the Gordon propeller technology and using Gordon designs. Certainly it carries a Gilkes serial number, for Gilkes carried on the consecutive serial numbers of their predecessors for all their turbines, and continue to do so to this day. Of particular interest in assessing the Gordon influence is the guide vane construction of No 3386, described in this study. Gordons used their own version of the Francis guide vane control system, in which the vanes were opened and closed by rotation of a large diameter annular ring, mounted on the crown plate, instead of the usual small ring encircling the main shaft with long links to the guide vanes, as used for example by Gilkes (Gilbert Gilkes 1911). Turbine No 3386 has a similar, if not identical, system to that used by Gordons, which was probably never used again, for Mr Jim Mattinson, a Gilkes fitter who maintained and installed turbines for over 50 years, reported that he had never seen another example of this particular guide vane operation (Jim Mattinson pers comm).

6.3 ASSESSMENT OF THE PUG MILL STRUCTURE

6.3.1 The Pug Mill building in its present form is primarily of nineteenth and twentieth century date, although it does contain relict features possibly dating to the eighteenth century. It is of particular interest in relation to the history of the Backbarrow site for two main reasons.

6.3.2 Firstly, the Pug Mill was possibly the location of a seventeenth century bloomery forge and later eighteenth and nineteenth century forges. This has not been confirmed by documentary evidence; however, the nature of the topography, its relationship to other features on site, and the nature of the water power supply system strongly suggest that this would have been the case. Map evidence suggests that a now demolished building to the south had a similar function, and the presence of substantial quantities of smithing slags in the riverbank at this point are indicative of nearby forging activity. This indication is further supported

by extant remains in the Pug Mill building itself of eighteenth or nineteenth century water power features. These features certainly pre-date the use of the site for hydro-electricity and would not have been required for the known or probable nineteenth century building functions as a store, foundry or small-scale smithy.

6.3.3 Whilst the documentary research did not produce conclusive evidence of the use of the site prior to the erection of the present structure, it is likely that there are buried features both within and around the Pug Mill building which may relate to these earlier periods.

6.4 ASSESSMENT OF THE TURBINES

6.4.1 The unusual features of the large turbine set this machine apart from the many turbines of similar output manufactured by Gilkes. It is the only example of a Gilkes-manufactured propeller-type water turbine of the early twentieth century, and may be the only propeller-type turbine in Cumbria, although this is uncertain. Even if others exist in Cumbria, as a unique machine made by a significant local manufacturer, it is of great historical interest in itself.

6.4.2 The power station is not of similar importance. The newly-installed hydroelectric plant to the north of the Pug Mill involved a very deep excavation of the area adjacent to allow the installation of three large turbine/generators, designed to supply power to the National Grid. The original water race and headstock have been much modified to suit the new installation, and its power station is set deep in the ground, probably at the same depth as the ground floor of the adjacent Pug Mill. The mass of concrete plugging the water intake pipe of the 1927 generator appears to be part of the foundations of the new building. In view of this newly-established use of the water supply for the new hydroelectric plant and the consequent interruption to the feed line of the old one, it is clear that the 1927 turbine cannot be operated again. Its historical value would therefore be restricted to a static display of hydroelectric power generation plant of the early twentieth century. Elements of the power station are relatively recent, the generator and the gearbox appear to be of 1950s manufacture, and the control cabinet seems even more modern, leaving the turbine wall plate, fly wheel and Gilkes governor as the only original features of importance. A similar installation also exists close to the Backbarrow Iron Works, at Low Wood, Haverthwaite. This was installed in the early 1950s, has two 218bhp Gilkes Francis turbines and is reported to have similar gearboxes and alternators to those at the Pug Mill (William Wilson pers comm).

6.4.3 Furthermore, the Pug Mill building, though very probably on the site of earlier metal-working facilities, had no direct involvement with the later smelting operations. Mr Peter Clark (pers comm), who operated the turbine for many years, revealed that it provided electrical power for general use in the iron-works until its closure in 1966, and, subsequently, was used to generate electricity for sale to the National Grid. Nevertheless, the southern part of the Pug Mill is particularly interesting in that it has an intact and rare large-diameter suction (discharge) tube

from the main turbine as well as a complete Gordon turbine with its own supply and suction tubes, both set in a former waterwheel pit and associated with a very obvious tail race. This provides an instructive general example of the progressive development of water power use which is extremely valuable.

7. RECOMMENDATIONS

7.1 RECOMMENDATIONS

7.1.1 ***The Pug Mill:*** it is recommended that the development and conversion should be allowed to proceed as this will ensure that the building is preserved and thus prevent its natural decay. However, the conversion of the building should involve as little intrusive disturbance to the existing fabri, in particular the central ground room (GF1), which contains the earliest fabric and should be as far as possible protected in the course of the conversion.

7.1.2 ***Water Power Installations:*** the large turbine is on the present evidence a unique Gilkes turbine and should be preserved, if possible *in situ*. The mechanical contents of the power station room at the north end of the eastern extension to the Pug Mill should be retained if this does not prove a major obstacle to the intended development of the site. It is recommended that the large turbine be left *in situ* in the penstock. The cast iron water feed pipe to the small turbine may be removed from the penstock pit and power station room.

7.1.3 The former wheelpit area with its Gordon turbine, water feed and discharge pipes, and the discharge pipe of the large turbine, should be retained essentially as it is with its present compliment of water power features, subject only to necessary restoration work.

7.1.4 ***Further Work:*** it is recommended that an instrument survey be undertaken to accurately record the phasing relationships on the south external elevation and to produce an accurate plan of the features located within the northern end of the tail race. As the majority of the earliest material is only visible internally it is strongly recommended that detailed elevations are produced of the internal elevations of the west cell of the ground floor (GF1), including any projection of these walls into the first floor. As large areas of these walls are obscured, either by stored equipment or by limewash/render, it is suggested that the recording is undertaken during the conversion of the building, to maximise the amount of detail visible. If the wall coverings are to be removed this should be undertaken under archaeological supervision.

7.1.5 Any external ground work should also be undertaken under archaeological supervision as it is likely that remains of water courses and possibly earlier structures lay close to the Pug Mill. If there is a requirement to lift the concrete floor in the ground floor room, there should be a programme of archaeological excavation to investigate evidence for any underlying hearths or structures relating to the use of the site as a forge.

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APPENDIX 1
PROJECT BRIEF

Brief for Archaeological Field Evaluation of the Pug Mill, Backbarrow Ironworks

Location: Backbarrow Ironworks, near Haverthwaite Cumbria.

Proposed: Restoration of Backbarrow Ironworks including the conservation and conversion of existing buildings and the construction of new buildings to form offices, workshops, live/work units and dwellings together with associated works.

Planning

Application No: 7/02/5383 (Rural Business Homes Ltd c/o Mason Gillibrand Architect, 16 Willow Mill, Caton LA2 9RA)

Summary

An application has been submitted to the Lake District National Park Authority for redevelopment of the Backbarrow Ironworks near Haverthwaite, Cumbria. This site was used for iron production from the 17th century until 1964 and is of crucial importance in the industrial history of the region. The remains include part of a blast furnace and associated structures including ore and charcoal storage buildings. It is likely that important subsurface features also survive. The majority of the site has been designated as a Scheduled Ancient Monument.

The archaeological potential of the majority of the site was evaluated in 1998 in conjunction with a previous planning application. However the Pug Mill at the northern end of the site was not evaluated during the previous work and is included in the current proposal for redevelopment. Some of the earliest fabric of this structure may date from the later 17th century when a bloomery forge is known to have operated in this location. The building was later extended and used to house turbines providing electricity and two of these still survive within the structure.

The English Heritage Inspector of Ancient Monuments and the National Park Senior Archaeologist have advised that the archaeological implications of the current proposal regarding the Pug Mill cannot be adequately assessed on the basis of the available information. The applicant has therefore been advised that an archaeological field evaluation should be carried out at this stage in order to obtain further information. This will be provided to English Heritage and the Lake District National Park Authority to be taken into account in determining the application for planning consent and the scheduled ancient monument consent that is also required for the current proposals. This recommendation is in line with government advice as set out in the DoE Planning Policy Guidance on Archaeology and Planning (PPG 16) and Policy NE 17 of the Lake District National Park Local Plan.

1. Location

1.1 The site is centred around national grid reference SD 533846, in the parish of Haverthwaite, Cumbria (see Map 1). The total area of the current proposal affects some 2 hectares, which is at present largely derelict.

1.2 The underlying geology of the site is Silurian slate and shale.

1.3 The site is currently owned by the Trustees of the A. While Estate and access should be arranged through their agent Mr Julian Lambton, Carter Jonas, 52, Kirkland, Kendal, Cumbria, LA9 5AP (Tel. 01539 722592).

2. Archaeological Background

2.1 The site of the proposed development includes the remains of the Backbarrow Ironworks which operated from 1711 until 1964. An earlier bloomery forge had been built on the site in 1685, probably on the site of the Pug Mill (Map 2 and Appendix 1, Fig. 3 building 34.1). The Backbarrow Ironworks is of great significance in the history of industry both regionally and nationally. It was possibly the earliest blast furnace in Cumbria; it operated for the longest period; and it was the last blast furnace in the country to convert from using charcoal as a fuel to using coke (in the 1920s). Important figures in the history of iron production that were associated with the site include Abraham Darby and Isaac Wilkinson. Because of its national significance, the site has been designated as a Scheduled Ancient Monument (Cumbria No 506). Its Cumbria Sites and Monuments Record reference is 3345.

2.2 Substantial remains of more recent activity on the site survive, including part of the blast furnace (the furnace stack), ore and charcoal storage buildings and other associated structures (Appendix 1, Fig. 3 and page 11). When the site closed in 1964 the final layout was fossilised and although some of the structures and other remains have now been demolished or removed, the basic layout of the site is largely intact. The survival of foundations and the availability of good documentary material (including photographs of the site in operation in the 1960s) would allow accurate interpretation of lost structures.

2.3 An assessment of the site, comprising limited documentary research and archaeological survey was carried out in 1992 by the Lancaster University Archaeological Unit (LUAU 1992). Part of the report arising from this work is reproduced here as Appendix 1.

2.4 In 1994 the entire site was recorded by the architectural section of the Royal Commission on the Historical Monuments of England (RCHME). This comprised production of an accurate ground plan of the visible remains and a photographic record of the standing structures. The survey data exists in both digital form and hard copy. The photography was oblique, not rectified, and no elevation drawings have been produced. Some of the conclusions of this work were published in English Heritage's publication *Furness Iron* (Bowden 2000).

2.5 In 1998 the site was subject to archaeological evaluation in connection with a planning application for redevelopment of the site by Ultratools Precision Mouldmaking Ltd. This exercise included trial trenching of the site but did not include a detailed assessment of the Pug Mill (LUAU 1998).

2.6 The Backbarrow Ironworks site has remained derelict since its closure in 1964. The Lake District National Park Authority has attempted for many years to identify an appropriate use of the site that accommodates protection of the important archaeological remains while maximising its development potential in terms of local employment. Following a commitment in the Lake District National Park Local Plan (1998) the LDNPA has published a Development Brief for the site (2001). In 1995 temporary repairs were carried out by the LDNPA and English Heritage to the roofs of the ore and charcoal storage buildings (Appendix 1, Fig. 3, buildings 7 and 8).

2.7 There are a number of other sites in the vicinity relating to woodland and other industries. Further details of these sites can be obtained from the Lake District National Park Authority, Murley Moss, Oxenholme Road, Kendal, LA9 7RL. Tel. 01539 724555/Fax. 01539 740822/Email EleanorKingston@lake-district.gov.uk

3. Requirement for evaluation of the Pug Mill

3.1 The Pug Mill is located at the northern end of the site and comprises an irregular, multi-phase two storey structure constructed of rubble with irregular block quoins and is built into the hillside and the dam of the pond (Bowden 2000, 69-70). It is likely that part of this structure incorporates elements of the bloomsmithy of 1685. The building appears to have been extended between 1846 and 1888 and was used as a workshop and turbine house. According to M. Davies-Shiel the original turbines were installed in 1866 and 1867 and were constructed by Williamsons. These were replaced in 1920 and 1927 with a "Kolumbi" with suction band (double action) and a "Gordon" (M. Davies- Shiel, undated postcard).

3.2 The current application for redevelopment of the site includes a proposal for conversion and reuse of the Pug Mill building. The Lake District National Park Authority and English Heritage have advised the applicant that further archaeological information is required for this structure in order to assess the implications of the proposal.

3.3 The objectives of the evaluation should be:

- To provide a detailed assessment and interpretation of the surviving fabric of the Pug Mill, including dating and phasing;
- To assess the survival and significance of any remains of the 1685 bloomsmithy;
- To assess and interpret the different functions of the building over time;
- To assess the reuse of materials in the existing fabric of the structure;
- To assess the survival and significance of the turbines housed in the Pug Mill together with any associated equipment;

3.4 Funding for the evaluation will be arranged by the applicant.

4. Scheduled Monument Consent

4.1 The Pug Mill comprises part of the Scheduled Ancient Monument, but as no intrusive techniques are required for this evaluation exercise, Scheduled Ancient Monument Consent will therefore not be required.

5. Evaluation Techniques

5.1 It is envisaged that the work will comprise three elements:

DOCUMENTARY RESEARCH

- Examination of any available maps (printed and manuscript), other relevant background material including publications, photographs, available family archives relating to past ownership; archives from previous archaeological work including the RCHME survey;

BUILDING SURVEY

- Visual inspection of the building and the surrounding area;
- Thorough examination and recording of the existing fabric in order to assess and interpret dating and phasing; to assess the survival and significance of any remains of the 1685 bloomsmithy; to assess and interpret the different functions of the building over time; and to assess the reuse of materials in the existing fabric of the structure;
- Recording of the detail of plan and elevations should be carried out by precise and informative annotation of 'as existing' drawings and photographs where these exist. Recent survey

drawings of the Pug Mill in plan and elevation are available in digital form from Mason Gillibrand Architects, 16, Willow Mill, Caton, Lancaster, LA2 9RA.

SURVEY OF MACHINERY

- Specialist assessment of the survival and significance of the turbines housed in the Pug Mill together with any associated equipment. This must be carried out by a person qualified in this field and should include documentary work and field inspection and recording;

7. Evaluation Proposal

A **detailed** evaluation proposal, including the following, should be prepared by potential contractors and submitted to the National Park Authority and English Heritage for approval:

7.1 A description of the proposed methods of documentary research, building recording and analysis and assessment of the turbines;

7.2 A projected timetable for the work including production of a report;

7.3 A description of Health and Safety provision;

7.4 A list of staff together with details of qualifications;

7.5 Any significant variations to the proposal must be agreed by the National Park Authority and English Heritage in advance.

8. Costings

8.1 A **detailed** breakdown of costs should be provided for the evaluation including documentary research, all fieldwork and final report production. If any contingency sums are considered necessary then this should be clearly stated.

9. Monitoring

9.1 The National Park Senior Archaeologist will be responsible for monitoring the evaluation. The archaeological contractor must give a minimum of one week's notice of the commencement of work to the Lake District National Park Authority so that arrangements for monitoring can be made.

10. Reporting Requirements

10.1 The evaluation should result in a final report including copies of the brief, specification and explanation of any departures from them; a description of the methodology employed; plans and sections at an appropriate scale; and appropriate photographs.

10.2 The objective account of the archaeological evidence recorded should be clearly distinguished from the interpretation of those features.

10.3 5 copies of the evaluation report should be deposited with the National Park Authority, on the understanding that it will be made available as a public document after an appropriate period (not exceeding 6 months from the completion of fieldwork). Copies will be forwarded to English Heritage, the Cumbria Sites and Monuments Record and the National Monuments Record.

10.4 The results of the work should be made available for publication in an appropriate journal or other publication and should include an account of the project and full details of significant finds, illustrated as appropriate. Details of the place and date of publication must be notified to the National Park Authority.

11. Deposition of Archive and Finds

11.1 The archaeological archive arising from the evaluation should be prepared with reference to conditions outlined by the United Kingdom Institute of Conservation (UKIC) and the Museums and Galleries Commission (MGC). It should be deposited in an appropriate local institution, in a format to be agreed with that institution. The National Park Authority, English Heritage and the Cumbria Sites and Monuments Record must be notified of the arrangements made.

APPENDIX 2
PROJECT DESIGN

Oxford
Archaeology
North

October 2002

BACKBARROW IRONWORKS

CUMBRIA

SURVEY OF THE PUG MILL
PROJECT DESIGN

Proposals

The following project design is offered in response to a request by Mason Gillibrand and in accordance with a brief by the Lake District National Park Authority, for an archaeological survey of the Pug Mill at the Backbarrow Ironworks, Cumbria.

1. INTRODUCTION

1.1 CONTRACT BACKGROUND

1.1.1 This project design is offered by Oxford Archaeology North (OAN) (formerly Lancaster University Archaeological Unit (LUAU)) in response to a request by Mason Gillibrand for an archaeological survey of the Pug Mill at Backbarrow Ironworks, Haverthwaite, Cumbria (SD 3555 8470) in advance of the development of the site. The evaluation follows on from an earlier evaluation by LUAU in 1998 (1998) and a survey of the artefacts in the Pug Mill in February 2000 (2000). The programme will involve a targeted documentary study of the Pug Mill, a fabric survey of the extant structure and an assessment of the extant turbine machinery in the Pug Mill. The site is a Scheduled Ancient Monument (AM 506), but as the programme will not have any destructive impact upon the building there is no requirement Class Consent or Scheduled Monument Consent.

1.2 HISTORICAL BACKGROUND

1.2.1 ***Summary History:*** there has been documented iron processing here since 1685, when John Machel built a bloomery forge until 1964, when the Backbarrow furnace closed. The blast furnace was built here in 1711 and, after a long and successful history, the furnace was, in the 1920's, the last British furnace to convert from charcoal to coke. During this period the site has seen considerable changes; during its life the furnace stack appears to have been rebuilt at least three times - in 1770, 1870 and finally in the 1920's as a result of the conversion from charcoal as fuel to coke. This conversion also resulted in substantial alterations to the works, as evidenced by surface photographs taken before and after the conversion (LUAU 1992).

1.2.2 ***Significance:*** the Backbarrow Ironworks is of very considerable archaeological significance, reflected in its scheduled status (AM 506). The Backbarrow site represents a small-scale, essentially eighteenth century, ironworks which has been modified throughout its history with the minimum of capital investment, and is now the only site in which many technological developments can be studied. It was the second blast furnace to be built in Cumbria, the first being at Cleator Moor (Riden 1987, 29-30 and Philips 1977, 26), and the last in Britain to convert to coke-firing. It also has a number of associations with important historical figures such as Wilkinson and Darby. Whilst a number of charcoal-fired blast furnaces survive in Britain, all are essentially eighteenth century in date and embody no nineteenth century developments (Crossley 1980, 3). The nineteenth century form of blast furnace, which differed markedly in its scale, build and site plan, has now totally disappeared; Backbarrow, therefore, is now the only site in Britain in which the development of the nineteenth century blast furnace technology can be demonstrated (Crossley 1980, 4).

1.2.3 ***Previous Work:*** the Backbarrow Ironworks was the subject of an archaeological investigation in 1992 by LUAU (1992) which involved an assessment of the ironworks in conjunction with a fabric survey of the furnace area. This was followed by a programme of survey by the Royal Commission on the Historical Monuments (England) which generated a ground plan of the whole site in conjunction with an oblique photographic survey of all the buildings. The LUAU survey generated elevation drawings for the furnace and roaster house, but otherwise there are no elevation drawings for the remaining buildings of the complex.

1.2.4 In 1998 LUAU (1998) undertook an evaluation and assessment of the site which was targeted on the impact area for a proposed development which was never implemented. This revealed extensive remains of twentieth century casting sheds immediately in front of the blast furnace, and in the southern part of the site were found extensive deep deposits of slag waste. A single trench was excavated on the west side of the road which revealed build up material for the floor of the scrap house and a post-hole was identified belonging to an earlier structure.

1.2.5 In 1999 LUAU (2000) undertook an archaeological inventory of artefacts contained within the Pug Mill (Turbine House). The investigation revealed less artefact material than had been anticipated,

but did identify a significant assemblage, which included iron bars, some stamped LORN and others VALLEY, there was also a single wooden mould, corresponding to the shape of the 'Valley' castings. The assemblage remarkably included an unopened wooden crate enclosing an unused black-leaded cast for one wheel of a hand-barrow, and was dated to 1958. From the adjacent river bank were five pigs of cast iron bearing the 'VALLEY' Stamp.

1.3 OXFORD ARCHAEOLOGY NORTH

1.3.1 Oxford Archaeology North (OAN) (formerly Lancaster University Archaeological Unit (LUAU)) has considerable experience of the archaeological survey and evaluation of sites and monuments of all periods, having undertaken a great number of small and large projects during the past 19 years. OAN has particular experience in the archaeological recording and analysis of standing ancient monuments, historic buildings and industrial landscapes. Projects have been undertaken to fulfil the different requirements of various clients and planning authorities, and to very rigorous timetables. OAN has considerable experience of the investigation of the North-West Iron and Steel industry. OAN (LUAU) undertook the assessment of the Backbarrow site in 1992, the evaluation in 1998 and the Pug Mill survey in 1999. OAN (LUAU) undertook an assessment of the Iron and Steel Industry Steps 2 and 3 as part of the English Heritage Monuments Protection Programme, during which the Backbarrow Ironworks was examined as part of that assessment. OAN (LUAU) undertook a detailed Level 3 survey of the Leighton Beck ironworks complex, near Arnside which was the sister ironworks to Backbarrow. OAN (LUAU) has undertaken a mitigative excavation of the Netherhall Blast furnace, in Maryport, Cumbria, and has just completed a survey and excavation of the associated coke ovens.

1.3.2 OAN has the professional expertise and resources to undertake the project detailed below to a high level of quality and efficiency. OAN and all its members of staff operate subject to the Institute of Field Archaeologists' (IFA) Code of Conduct. OAN is a registered organisation of the IFA (No 17).

2. OBJECTIVES

2.1 INTRODUCTION

2.1.1 The following programme has been designed in accordance with a brief by the Lake District National Park Archaeologist to enable an investigation of the Pug Mill. This is required so as to:

- provide a detailed assessment of the surviving fabric of the Pug Mill
- assess the potential for survival of the 1685 bloomsmithy
- assess the different functions of the building over time
- assess the reuse of materials in the extant structure
- assess the survival and significance of the turbines present in the Pug Mill.

2.2 DOCUMENTARY STUDY

2.2.1 An enhancement of the existing documentary studies will be undertaken to investigate the history and development of the Pug Mill.

2.3 FABRIC SURVEY

2.3.1 A survey will be undertaken of the Pug Mill, based on existing plans and elevations and this will, examine the development of the building and any evidence for the seventeenth century bloomsmithy**.**

2.4 TURBINE SURVEY

2.4.1 Assessment of the extant turbine machinery, to be undertaken by an appropriate specialist.

2.5 SURVEY REPORT

2.5.1 A written survey report will assess the significance of the data generated by this programme within a local and regional context.

3. METHOD STATEMENT

3.1 In line with the objectives and stages of the archaeological work stated above the following work programme is submitted.

3.2 DOCUMENTARY SURVEY

3.2.1 The following will be undertaken as appropriate, depending on the availability of source material. The assessment is intended to follow on from the earlier assessments undertaken of the site, and will be targeted specifically at the Pug Mill, which was not examined in detail during the earlier study.

3.2.2 ***Documentary and Cartographic Material:*** this work will rapidly address the potential sources of information identified by the Backbarrow Ironworks assessment (LUAU 1998):

Cumbria Record Office (Barrow) - including the BDB/2 Charcoal Iron Company ltd, Backbarrow records

Lancashire Record Office - including DDmc the muniments of the Machell family

3.2.3 It will examine the potential of private collections, particularly those of Dennis A While and Mike Davies-Shiel and would involve close consultation with Mike Davies-Shiel.

3.2.4 The emphasis of the documentary study will be on investigating early maps or photographic material which may inform the developmental sequence of the mill. However, it will also include an appraisal of secondary sources and such primary documentation as may be reasonably available. Published documentary sources will also be examined and assessed.

3.2.5 ***Analysis:*** a programme of analysis will examine the development of the site, and will examine the locational evidence for the early iron working structures on the site. It will present the evidence for the site plan at different stages of development. The analysis will appraise the Pug Mill site within a national context and will appraise the archaeological significance of the extant turbines.

3.3 BUILDING SURVEY

3.3.1 A fabric survey will be undertaken of the Pug Mill, in order to provide a record of the structure prior to any intervention, and to enable a programme of analysis to assess the development of the structure.

3.3.2 ***Photographic Archive:*** a photographic archive will be produced utilising a 35mm camera to produce both black and white contact prints and colour slides. The archive will comprise general shots of the buildings (both internal and external) and their surroundings and detailed coverage of architectural features.

3.3.3 ***Site Drawings:*** plans and elevations have been produced for the building by the architects (Mason Gillibrand), and it is therefore proposed to augment these drawings rather than create a new survey.

The existing drawings will be enhanced to show important architectural detail and which will provide the basis for fabric analysis. The fabric recording will be undertaken by manual survey onto paper copies of the architects drawings. The alterations will then be incorporated into a CAD system to produce the final drawings. The drawings will usually be produced at a scale of either 1:50 or 1:100. The final product of the survey will be the following.

Ground and First Floor Plans

A single cross section through the building

East, north, west and south external elevations

3.3.4 ***Interpretation and Analysis:*** a visual inspection of the building and the surrounding area will be undertaken; the recording of the building will utilise the OA North buildings proforma sheets and an outline description will be maintained to RCHM(E) Level II type survey. This level of recording is descriptive and will produce an analysis of the development and use of the building. The analysis will examine if there is any extant evidence for the 1685 bloomsmithy, and the earlier turbines. The survey will assess the reuse of buildings in the extant structure.

3.4 SPECIALIST SURVEY

3.4.1 A survey is required of the extant machinery to establish its condition, and importance. The turbines that were put into the Pug Mill in the 1920's were built by Gilbert, Gilkes and Gordon Ltd of Kendal, a company which is still in business, and which maintains records of its earlier installations. It is proposed to investigate the records of the company and to use a specialist consultancy to assess the importance and significance of the turbines. It is proposed to use Sam Murphy, who has undertaken extensive research into the history of Greenside Mines and who, as part of that and similar studies, has undertaken considerable research into the turbines of Gilbert, Gilkes and Gordon Ltd.

3.4.2 The work would involve background research into the turbine machinery, setting it within the context of other manufacturers and installations within the country. A field inspection would be undertaken by Sam Murphy, in conjunction with members of OA North staff, who would undertake a basic level of recording. This would entail a detailed photographic record, and the production of a gazetteer of the principal components. The latter would be linked into the documentary record that would be established for the machinery.

3.5 SURVEY REPORT

3.5.1 ***Archive:*** The results of Stages 3.1-3.4 above will form the basis of a full archive to professional standards, in accordance with current English Heritage guidelines (*Management of archaeological projects*, Second Edition, 1991). The project archive represents the collation and indexing of all the data and material gathered during the course of the project. The deposition of a properly quantified, ordered, and indexed project archive in an appropriate repository is considered an essential and integral element of all archaeological projects by the Institute of Field Archaeologists in that organisation's Code of Conduct. This archive will be provided in the English Heritage Central Archaeology Service format, as a printed document, and a synthesis (the evaluation report and index of the archive) will be submitted to the relevant Sites and Monuments Record.

3.5.2 The archive will be formed of all the primary documentation, including the following:

- Survey Information
- Context Records
- Field / Inked Drawings and digital copies of CAD data
- Photographic negatives, prints and colour transparencies

- Written report
- Administrative records

3.5.3 ***Interim Report:*** An interim report will be completed as soon as the raw data has been captured. This will provide a brief overview of the results and will provide an assessment of the significance of the monument.

3.5.4 ***Report:*** one copy of a written synthetic report will be submitted to the client and further copies will be submitted to the Lake District National Park Authority and English Heritage which will be delivered within five weeks of completion of the field work. If required an initial interim report can be produced shortly after completion of the field work. The report will present, summarise, and interpret the results of the programme detailed in Stages 3.1-3.5 above, and will include an index of archaeological features identified in the course of the project, with an assessment of the sites development. It will incorporate appropriate illustrations, including copies of the site plans and elevation drawings, and the topographic survey mapping all reduced to an appropriate scale. The report will consist of an acknowledgements statement, list of contents, executive summary, introduction summarising the brief and project design and any agreed departures from them, methodology, interpretative account of the site and associated structures, list of archive contents, a complete bibliography of sources from which data has been derived, and a list of further sources identified during the programme of work. The report will make recommendations for further mitigative recording if required.

3.6 GENERAL CONDITIONS

3.6.1 ***Access:*** it is understood that the client will ensure pedestrian and vehicular access to the site.

3.6.2 ***Health and Safety:*** full regard will, of course, be given to all constraints (services) during the survey, as well as to all Health and Safety considerations. The OAN Health and Safety Statement conforms to all the provisions of the SCAUM (Standing Conference of Unit Managers) Health and Safety manual. Risk assessments are undertaken as a matter of course for all projects. The Unit Safety Policy Statement will be provided to the client, if required. The survey will not examine the blowing house because of the risk of ingesting asbestos from the cladding within the building. Trenches will be excavated up to one metre away from any standing walls to present any risk of destabilisation of structures.

3.6.3 ***Confidentiality:*** The report is designed as a document for the specific use of the client, the Lake District National Park Authority and English Heritage, for the particular purpose as defined in this project design, and should be treated as such. Any requirement to revise or reorder the material for submission or presentation to third parties or for any other explicit purpose can be fulfilled, but will require separate discussion and funding.

3.6.4 ***Project Monitoring:*** any proposed changes to this project design will be agreed with the client, the Lake District National Park Archaeologist and the English Heritage Inspector of ancient monuments.

3.6.5 ***Insurance:*** the insurance in respect of claims for personal injury to or the death of any person under a contract of service with the unit and arising out of an in the course of such person's employment shall comply with the employers' liability (Compulsory Insurance) Act 1969 and any statutory orders made there under. For all other claims to cover the liability of OAN, in respect of personal injury or damage to property by negligence of OAN or any of its employees, there applies the insurance cover of £ 2m for any one occurrence or series of occurrences arising out of one event.

4. WORK TIMETABLE AND RESOURCES

4.1 TIMETABLE

4.1.1 It is envisaged that the various stages of the project outlined above would follow on consecutively, where appropriate. The phases of work would comprise:

i	***Documentary Study***
	5 days
ii	***Fabric Survey***
	2 days (on site)
iii	***Machinery Survey***
	1 day (on site)
iv	***Interim Report***
	1 day (office)
v	***Evaluation Report***
	8 days (office).

4.1.2 OAN can execute projects at very short notice once an agreement has been signed with the client. The project (field work, report and archive) is scheduled for completion within three weeks from the completion of the field work.

4.2 RESOURCES

4.2.1 The project will be under the project management of **Jamie Quartermaine, BA Surv Dip MIFA** (OAN Project Manager) to whom all correspondence should be addressed. Jamie Quartermaine undertook the fabric survey of the Backbarrow furnace as part of the 1992 LUAU assessment and has acted as project manager on all subsequent archaeological works. He also undertook the detailed survey of the Leighton Beck Ironworks and the fabric survey of the Netherhall Blast Furnace, undertaken alongside the excavation.

4.2.2 It is proposed that the study be undertaken by **Ian Miller BA AIFA** (Project Officer) who has considerable experience of the recording of industrial sites and undertook the excavation of the Netherhall blast furnace at Maryport.

4.2.3 All Unit staff are experienced, qualified archaeologists, each with several years professional expertise.

ILLUSTRATIONS

PLATES

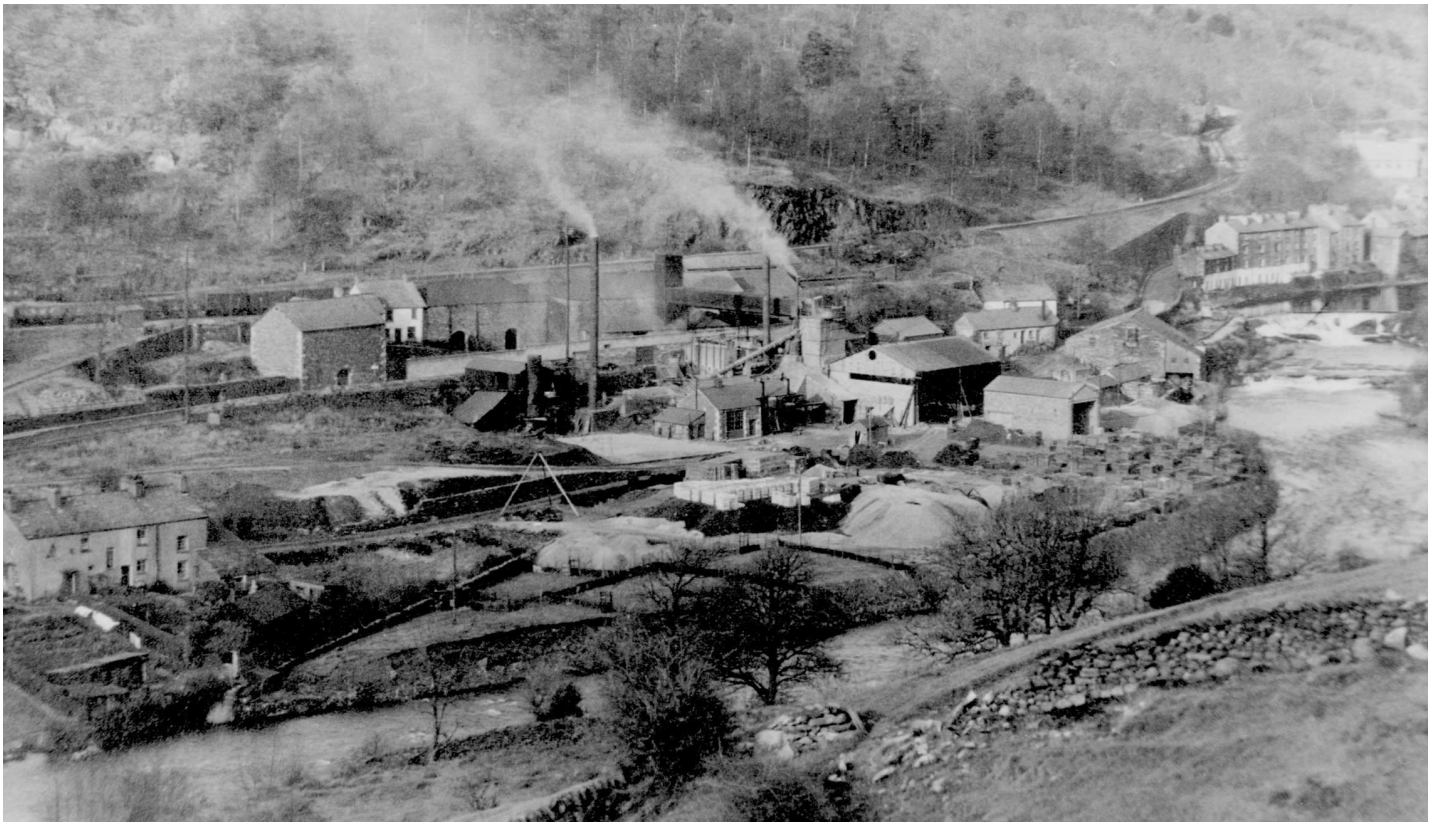

Plate1: Photograph of Backbarrow Ironworks showing the Pug Mill from the south-east – late 1920s/ early 1930s (LDNPA)

Plate 2: Ground floor room 1 (GF1) showing the western wall

Plate 3: Ground Floor (GF1)

Plate 4: Ground Floor (GF1)

Plate 5: East facing elevation

Plate 6: West facing elevation showing architectural detail

Plate 7: North facing elevation

Plate 8 South facing entrance to the mill

Plate 9 North facing elevation

Plate 10

Plate 11

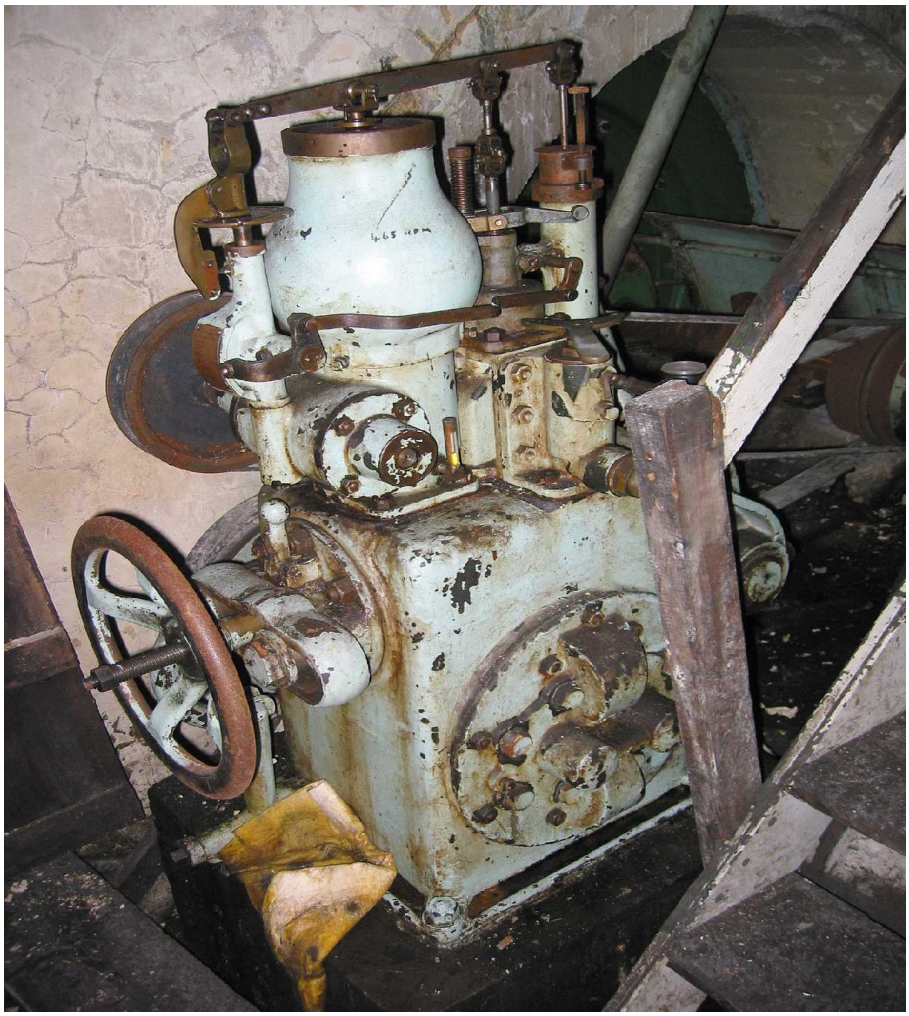

Plate 12

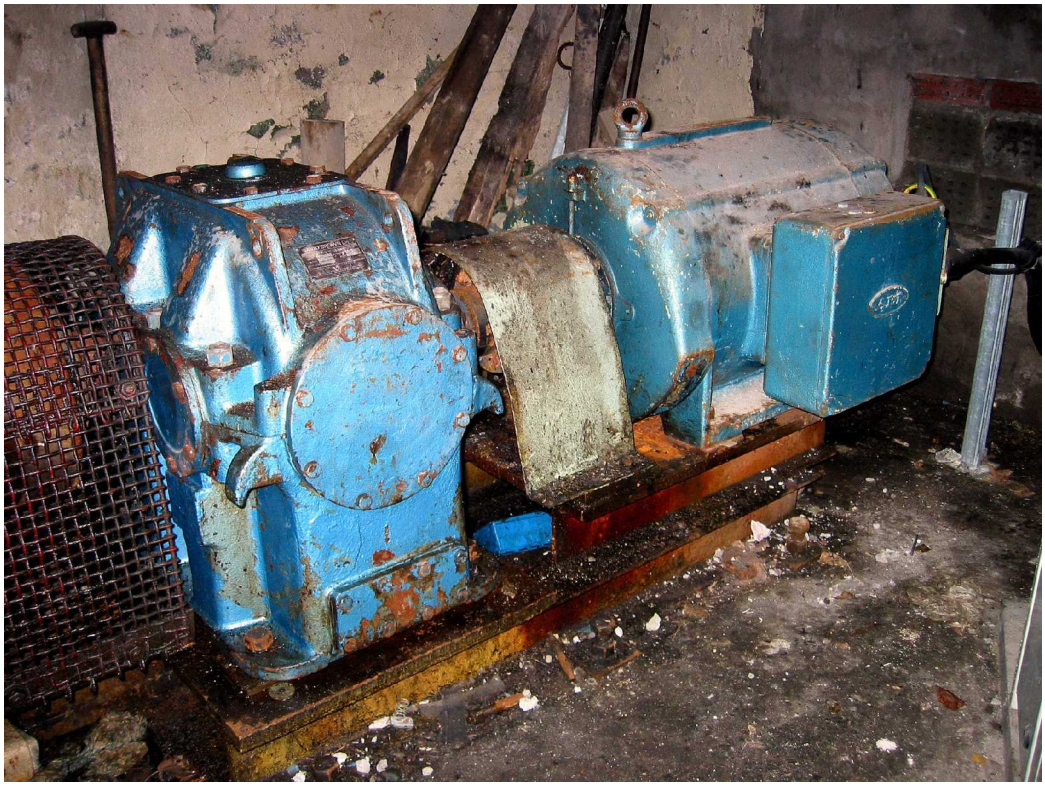

Plate 13

Plate 14

Plate 15

Plate 16

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