The JESSOP Consultancy
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BOILER HOUSE WALL: WINDING ENGINE HOUSE,
MIDDLETON TOP, DERBYSHIRE

Archaeological Building Survey

October 2016

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SUMMARY OF PROJECT DETAILS

OASIS ID:	Thejesso1-263 195
TJC Project Code:	MBH16
Project Type(s):	Historic Building Survey – Level 2
	B/w Photography
National Grid Reference:	SK 27598 55179 (DE4 4LS)
County:	Derbyshire
District/Unitary Authority:	Derbyshire Dales
Parish:	Middleton
Elevation (above sea level):	c.300m
Designation Status(s):	Scheduled Monument (NHLE:1007038)
HER Record No(s):	28325
Prepared by:	Oliver Jessop MCIfA
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Reviewed by	Manda Forster PhD MCIfA
Date:	October 2016
Version:	Final (25.10.16)

TABLE OF CONTENTS

NON-TECHNICAL SUMMARY

This report details the results of an archaeological building survey of the north wall of the boiler house at Middleton Top Winding Engine House, Middleton, Derbyshire; it is centered on NGR SK 27598 55179. The building forms part of the former Cromford and High Peak Railway and is designated as a Scheduled Monument – No.1007083. The survey has been prepared to inform a programme of conservation repairs, that may involve the dismantling and rebuilding of the whole of the gable wall.

The archaeological survey has comprised of archive research, a measured survey of the internal and external elevations of the wall and b/w photography. To compliment the building survey, eight mortar samples were taken. Six of the samples were subjected to chemical analysis by Hirst Conservation, the results of which will be used to determine suitable mortar mixes for the repair programme.

The survey has identified six phases of alteration within the building fabric, all represented within the north wall of the boiler house. This elevation can be subdivided into two parts, being divided by a large horizontal lintel c.2.1m above the ground level. This beam created a self-supporting opening above the boilers, which would have enabled the brickwork below to be removed for periodic inspections of the metalwork every six years. Above the lintel, which was formed from two separate timbers a diagonal construction break has been recorded. This feature indicates that the existing roof pitch of 26 degrees replaced an earlier lower roof, which had a pitch of c.15 degrees.

During the any rebuilding of any brickwork within the upper part of the gable and in-between the boilers, the mortar analysis indicates that a hydraulic mortar mix which has a strength of NHL 5 would be appropriate. This may be coloured, depending upon where in the brickwork it is located. Externally, a grey colour is prevalent, whilst internally, the lower part of the wall has a buff composition.

The site archive has been deposited with the Derbyshire Record Office in Matlock and the report uploaded to the OASIS (Online AccesS to the Index of archaeological investigationS) digital archive with the reference number: ***thejesso1-263 195****.*

It is recommended that during the repairs to the building that an intermittent archaeological watching brief is maintained to document aspects of the building that are currently obscured, or inaccessible. This should be undertaken by a suitably qualified and experienced industrial archaeologist, who is a member of the Chartered Institute for Archaeologists.

1 INTRODUCTION

BACKGROUND

This document presents the results of a historic building survey of the southern gable wall of the boiler house that is attached to the east side of the two-storey winding house at Middleton Top, Middleton, Derbyshire (**Figure 1**). It has been prepared to provide supporting information for a repair programme that seeks to replace a failed timber joist and will involve the dismantling and rebuilding of the gable wall.

The building is a Scheduled Monument - No.1007038 (**Appendix 4**). It is owned and managed by Derbyshire County Council.

AIMS

The primary aims of this archaeological survey have been to survey, identify and interpret the north gable of the boiler house at Middleton Top. The lower half of the wall contains two larger boilers and this survey has attempted to understand in greater detail how they operated.

A secondary aim has been to establish the mortar composition of the different structural phases of the wall, which can be used to guide the repair programme.

PRINCIPAL DELIVERABLES DERIVING FROM THIS WORK:

- To produce a elevation drawings of the boiler house wall enhanced with archaeological information;
- To establish the constructional sequence of the extant historic fabric;
- To produce a series of b/w photographs that will be deposited in the Derbyshire archives in Matlock;
- The preparation of an interpretative report that provides a discussion of the building;
- To take mortar samples from each structural phase.

DISSEMINATION

Copies of this report will be distributed to the Client, the Derbyshire Historic Environment Record (HER), the Derbyshire Record office, and a digital copy will be uploaded to the OASIS (Online AccesS to the Index of archaeological investigationS) with the reference number: **thejesso1-263 195**.

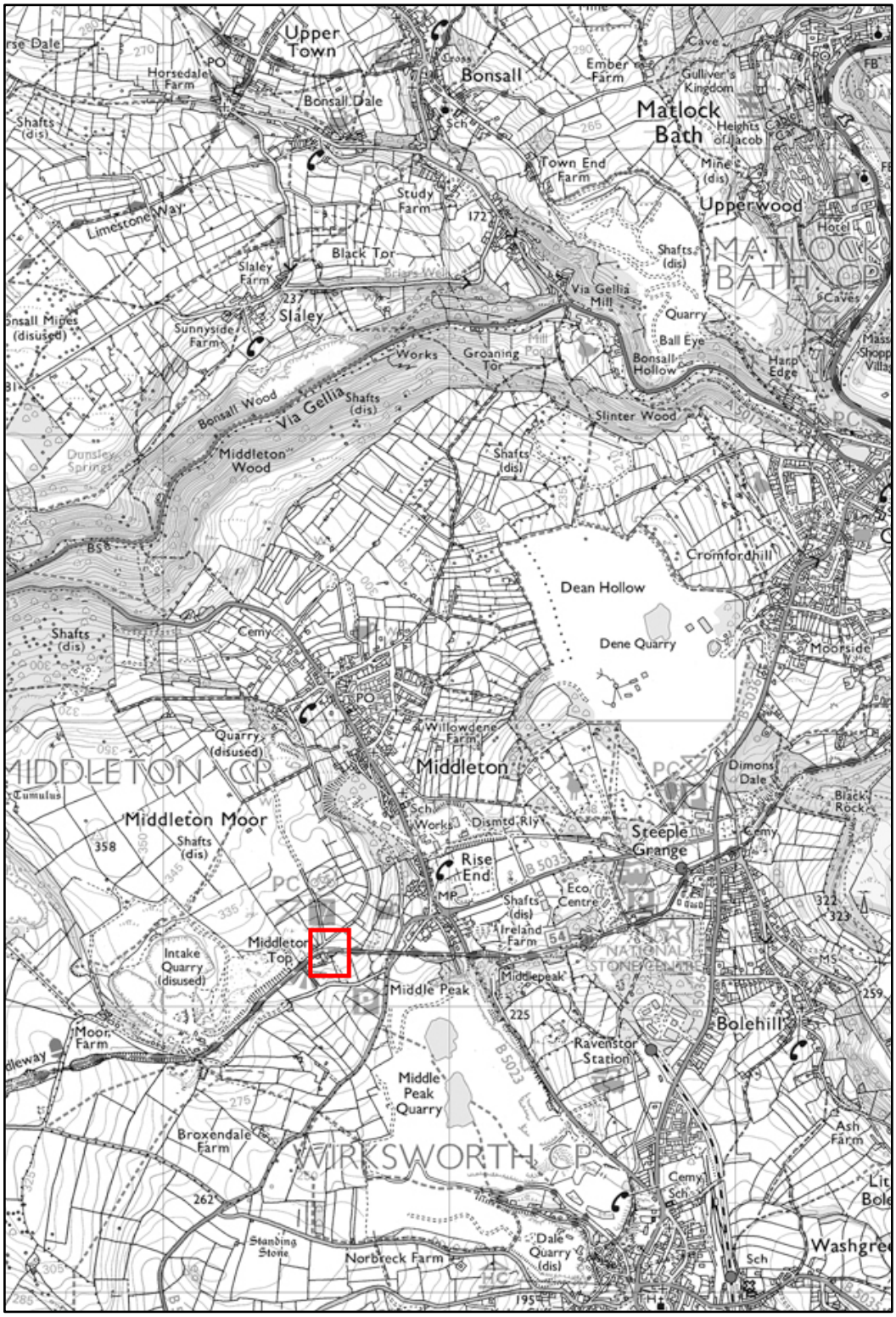


Figure 1: Location of the site

2 SITE LOCATION AND BASELINE CONDITION

LOCATION OF SITE AND SETTING

The winding house at Middleton Top is located at the top of the steep Middleton incline (**Figure 2**) on the edge of the village of Middleton, Derbyshire; centered on NRG: SK 27598 55179 (**Figure 3**). The incline is 708 yds (647. 4 metres) long, with a 1 in 8 and a quarter gradient.

The boiler house has a rectangular footprint and has been built against the east wall with a high single-pitched roof. Access into the boiler house is via a ground level doorway in the southwest corner and an internal doorway that connected directly to the Engine House at first floor level. Internally there is a small lobby area in the southwest corner of the ground floor that leads to a storeroom. The majority of the ground floor contains the two cylindrical metal boilers, both of which are largely concealed from view being encased by brick walling. A flight of timber steps from the lobby provides access to the first floor, which is level with the top of the two boilers.

To the south of the boiler house is an area of paved brick, with a low retaining wall around the edge. Beyond this is the site of former sidings, an engine shed (now removed) and the tracked of the Cromford and High Peak Railway.

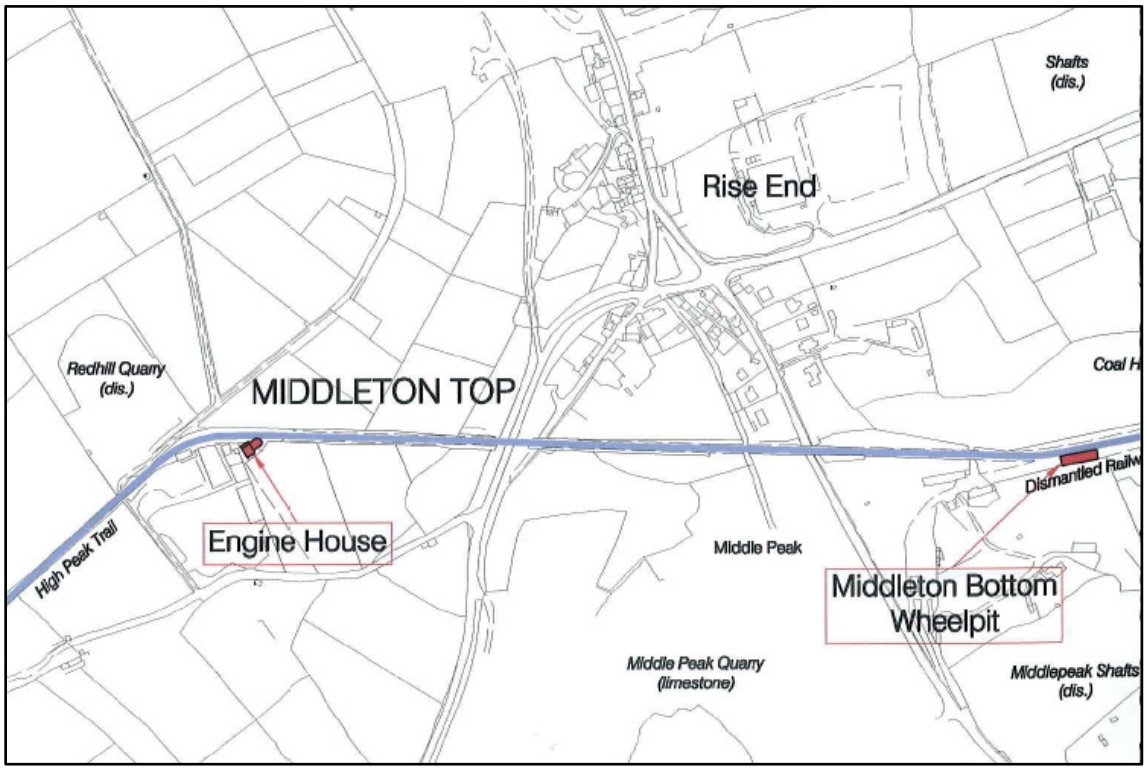


Figure 2: Plan of incline and Middleton Top (after DCC 1999)

GEOLOGY

The underlying bedrock geology beneath the site is Monsal Dale Limestone Formation – Limestone, a sedimentary bedrock. No superficial deposits are recorded (BGS Digital data 2016).

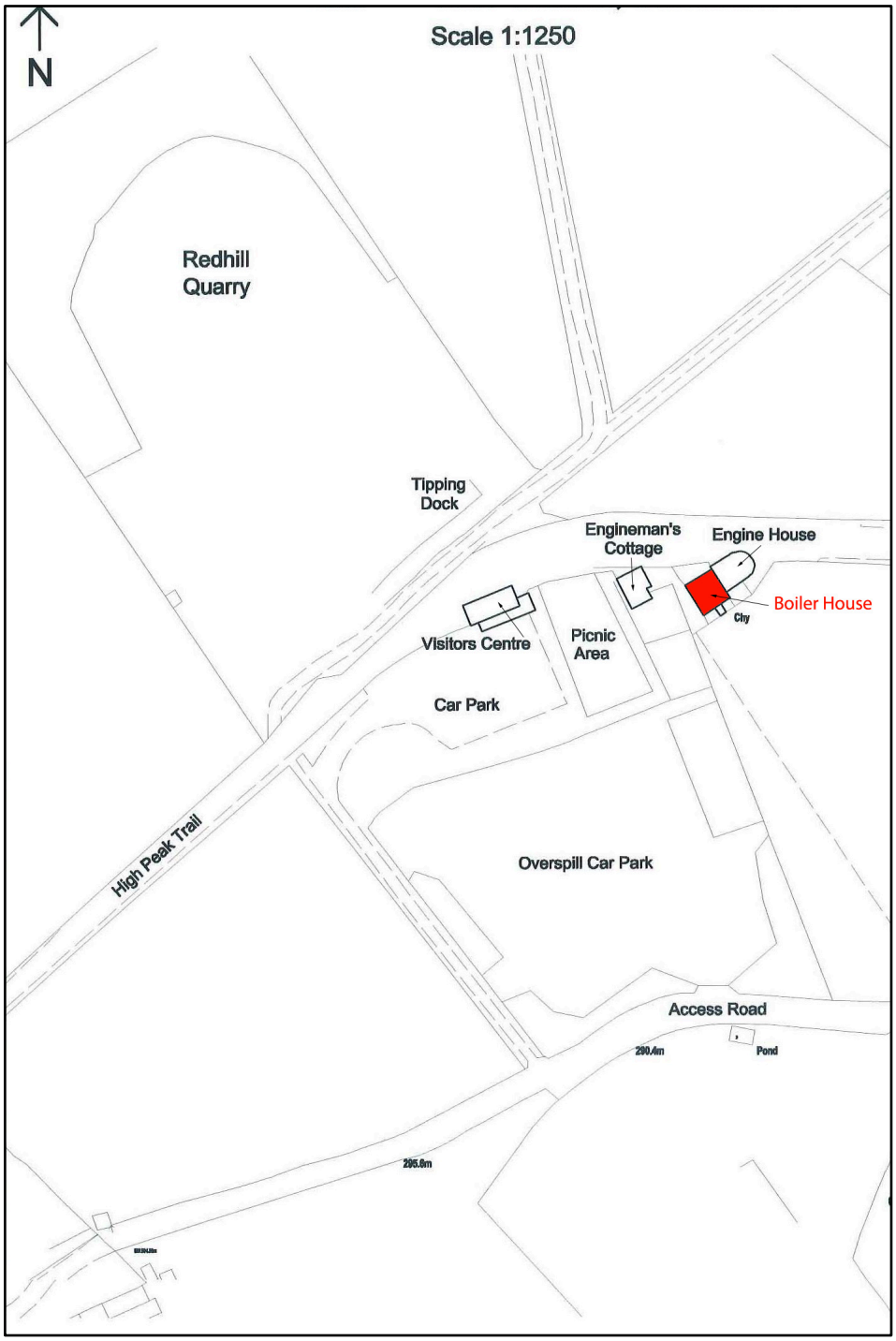


Figure 3: Plan of Middleton Top (after DCC 1999)

3 METHODOLOGY

INTRODUCTION

This archaeological building survey has been prepared in accordance with a guidance prepared the Chartered Institute for Archaeologists (ClfA 2014) and Historic England (HE 2016). The project methodology has comprised of a series of stages, including a review of previous work, a site survey, photography and mortar analysis.

The survey has been undertaken with reference to an outline scope of works detailed by Tim Allen (Historic England Inspector) and that was agreed with Alex Gilbert (Conservation Officer) of Derbyshire County Council. The project has been coordinated by Mia Lodge (Assistant Building Surveyor) of Derbyshire County Council.

LIMITATIONS

The building survey has examined all readily accessible areas of the south wall of the building. It should be noted that the hidden spaces around each of the boilers was not accessed. The internal section of the wall was partially obscured by a display of historical fixtures and fittings from the railway. The first floor was also largely obscured by stored materials.

The scope of the report is limited to:

- Consultation with architectural plans produced for alterations to the building;
- Review of relevant archive and documentary material;
- Detailed site survey comprising of measured drawing and photography;
- Sampling (x8) and analysis of mortar (x6);
- The preparation of this report and a fieldwork archive.

NOMENCLATURE

The terminology used throughout this document has been derived from existing names and descriptions associated with the Cromford and High Peak Railway, winding engines and boiler houses from the 19th century. It should be noted that future research may identify additional descriptions for specific aspects of the site.

SITE SURVEY

Elevation drawings of the south gable of the boiler house were produced at a scale of 1:20. These were derived from photogrammetry using Agisoft Photoscan software, and then drawn up on site using permatrace and hand measurement to identify features of archaeological significance.

To accompany the drawn record a b/w (35mm) photographic survey has been undertaken to record the building and its wider historic setting. All elevations (interior and exterior) and architectural details have been photographed. The locations of the photographs have been recorded on a site plan and documented on a pro-forma register (see **Appendix 3**).

The site was inspected by Oliver Jessop MCIfA on three occasions during June, July and August 2016.

Documentary and archive research

A review of any available surveys has been undertaken to identify gaps in knowledge, and to ensure that the full historical development of the building is understood.

The following archaeological databases and archive repositories were consulted:

- Archaeological Data Service (ADS) – York;
- Derbyshire Record Office;
- Derbyshire Historic Environment Record;
- Derbyshire County Council Conservation and Planning Records;
- Geological mapping;
- Heritage Gateway;
- Historic England Archive (red boxes);
- Historic England case file (information provided by Tim Allen);
- Historic mapping including relevant Ordnance Survey Maps;
- Internet archives;
- National Heritage List for England – Historic England.

Mortar Sampling

The mortar sampling was undertaken in accordance with established sampling techniques, details of the methodology and results are presented in **Section 6** of this document.

Research Questions

No formal research questions have been considered during this archaeological survey.

4 UNDERSTANDING THE SITE - HISTORY

INTRODUCTION

This section of the report presents a summary history of the Cromford and High Peak Railway and development of Middleton Top. It has made reference to the previous historical published and archive sources (see bibliography). Relevant visual sources including maps and photographs are included as **Appendix 1**.

THE CROMFORD AND HIGH PEAK RAILWAY

The Cromford and High Peak Railway (C&HPR) was authorised by Act of parliament in 1825, although was built in stages, and opened to commercial operations in 1830 and 1831. Its purpose was to link the Cromford Canal with the Peak Forest Canal at Whaley Bridge 34 miles to the north, thus forming at integral aspect of the canal network.

The route of the railway and structural elements were engineered by Josias Jessop and was designed as a series of level sections of track that were connected by nine inclined planes. The route was characterised by its development of the principles of canal engineering, which had tight curves and followed natural contours within the upland landscape of the Peak District.

Each of the inclined planes (apart from at Whaley Bridge) were operated by a stationary steam powered winding engine (**Appendices 1.3, 1.4**). Middleton Top engine house is the only survival.

The development of the rail network in the 19th century gradually impacted upon earlier transport routes such as canals. This resulted in the amalgamation of the C&HPR with the London and North Western Railway (LNWR) in 1887. The railway became part of the London, Midland and Scottish Railway (LMSR) in 1923, then became incorporated into British Railways in 1948. Middleton incline was finally closed in 1963, followed by the rest of the remaining sections of line in 1967.

The trackbed was acquired by Derbyshire County Council and the Peak Park Joint Planning Board, finally being adapted to open as a long distance trail in 1974.

MIDDLETON TOP

The early development of Middleton Top as part of the C&HPR is poorly documented, with the earliest plan being the 1848 tithe map (**Appendix 1.1**). This map depicts the engine and boiler house and the engine mans cottage to the west. A large sub-rectangular area further west represents two water filled ponds, labelled as 'meer'. This was used to provide water for the boilers and later on for locomotives running along the straight sections of track. A small enclosure

with a building at the far western end of the site is the 'coal wharf', where coal was stockpiled. The route of the railway is marked with allotments of agricultural land on either side.

The general layout of the site has remained relatively unaltered thought the first half of the 20th century (**Appendix 1.2**) until the 1960s when the railway was decommissioned. Following the removal of the track, a timber engine house (**Appendix 1.5**) and a stationary steam engine (**Appendix 1.6**) were removed in preparation for conversion of the site into a public trail. The reservoir has been largely in-filled and is beneath the site of the car park and picnic area.

MIDDLETON TOP WINDING ENGINE

The Middleton Top winding engine house is the oldest railway winding engine in the world and the beam engines are the oldest rotative stream engines on their original site (**Appendices 1.7, 1.8**). In recognition of this, the site has been designated by the Secretary of State as a Scheduled Monument as a pioneering example of industrial heritage. The monument comprises of the winding engine house and an attached boiler house.

The engine house is constructed of dressed, ashlar cut, mortared gritstone blocks laid in regular and even courses. The building is approximately 10m x 6m and 10m high, and has a pitched slate roof. The building has three storeys, including a lower one below ground level. The wheel for the rope guides is mounted on the side of the engine house.

The engine was built in approximately 1825 and was in use until 1963, when the railway closed. The engine was a two cylinder, low pressure, condensing beam type, valves operated by a parallel motion, with a 14 ft (4.27m) diameter fly-wheel. The winding wheels were set into a sunken chamber below the engine. The engine was made by the Butterley Ironworks.

THE BOILER HOUSE

The boiler house is constructed of red brick and gritstone, with a mono-pitched slate roof. It houses two large boilers, the ends of which project from the north elevation of the building. The building is approximately 7m x 7m and stands 6m high. The chimney for the boiler is attached to the side of the boiler house. The base of the chimney is constructed of gritstone blocks, while the main body is of brick strengthened by metal ties. The chimney stands 30-40m high.

The pair of boilers are a Cornish design, that comprise of a single furnace tube installed with side and sole flues to transfer hot gases along the outside of the boiler prior to reaching the chimney. These boilers are 22 feet long and replaced the original wagon boilers being installed in c.1869, probably by the LNWR.

These boilers were capable of producing steam at 5 pounds per square inch, and were numbered by the LNWR as numbers 303 and 304. The eastern boiler has a curved patched repair above the furnace tube, installed in 1916 following its failure after an inspection test two years before in 1914. Interestingly, it is this repaired boiler that was kept working the longest, finally being decommissioned in 1957. Steam was then generated from a stationary locomotive engine that was located to the northwest of the boiler house (see **Appendix 1.5**), which produced 150 pounds of pressure per square inch, but with a reduction value the pressure was lowered to 5 pounds.

5 UNDERSTANDING THE SITE – HISTORIC FABRIC

INTRODUCTION

This section of the report presents the results of the archaeological building survey and analysis of the exposed historic fabric that forms the north wall of the boiler house. To accompany the written description a series of drawings have been prepared (**Figures 4-6**) and reference photographs of the various structural elements are included as **Appendix 2**. The exterior is described first, followed by the interior walling.

The building is orientated on a north-south alignment (**Figure 4**).

PHASED DEVELOPMENT

The building can be sub-divided into six phases of development and alteration.

Phase 1	External east boundary wall made of gritstone and contemporary with the Winding House and Chimney, possibly forming external yard
Phase 2	Construction of brick walled boiler house with a double timber lintel above a pair of Cornish boilers, c.1869
Phase 3	Construction of covered boiler house with a pitched roof (15 degree angle)
Phase 4	Raising of pitched roof to a slope of 26 degrees
Phase 5	Construction of the brick wall between the boilers
Phase 6	Decommissioning and adaptation of the building for visits by the general public

DESCRIPTION OF FABRIC – EXTERIOR

The building has a very simple layout (**Figure 4**), comprising of a building built against the east gable of the Winding House and north side of the chimney with an external footprint of c. 7m x 7.6m. The boilers (**Appendix 2.7**) face the former sidings and track that formed the C&HPR.

There is a vertical construction joint at the interface of the gable with the Winding House, confirming that the boiler house is a secondary addition. It should however be noted that the east wall of the boiler house is built over a gritstone wall 0.64m wide and 1.5m in height. This wall is interpreted as being contemporary with the construction of the Winding House, and potentially represents the remnants of a boundary wall around an external yard that may have housed a pair of haystack boilers in the primary phase of construction.

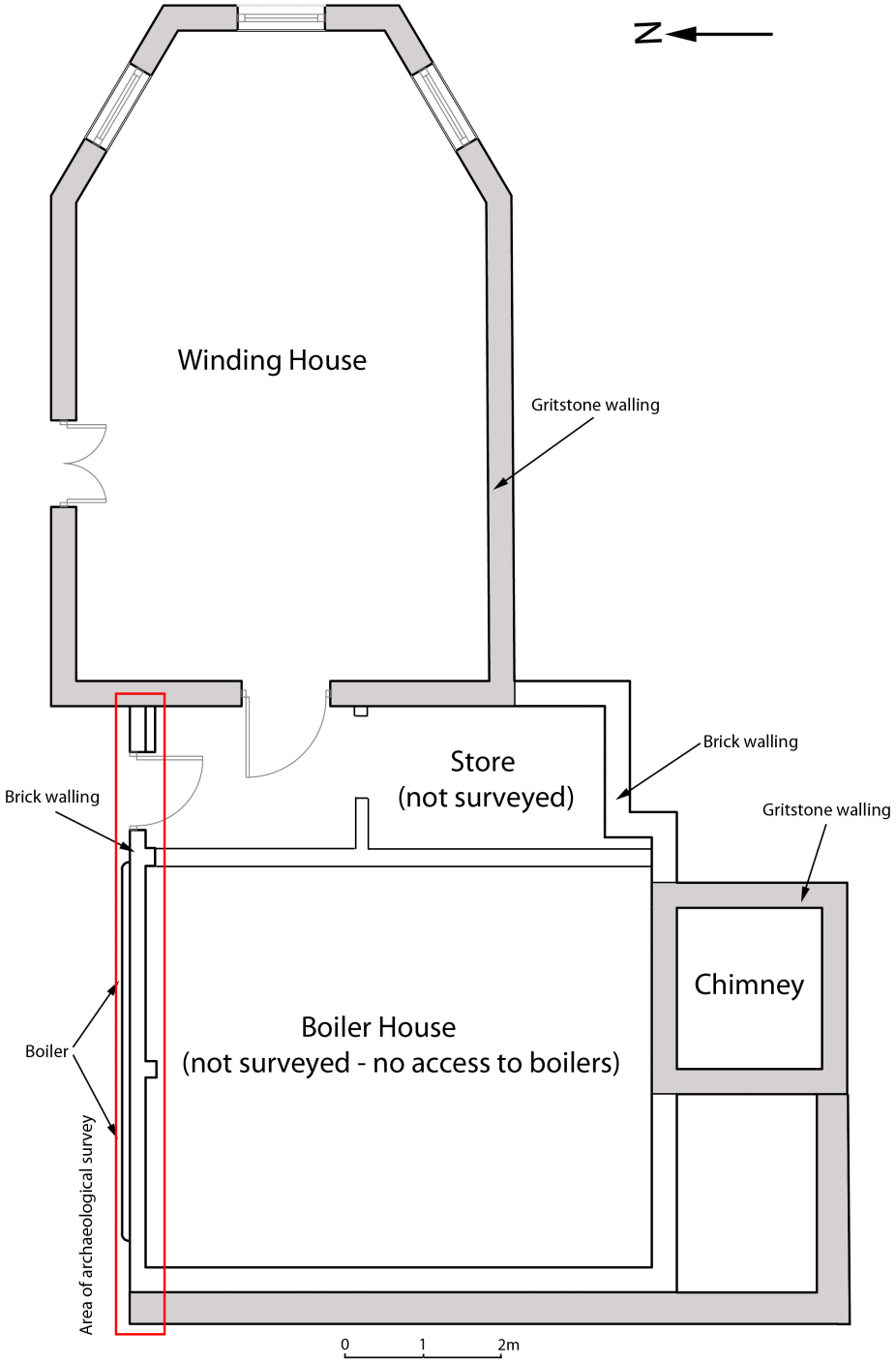


Figure 4: Layout of winding house and boiler house (after DCC 2016)

The external elevation of the boiler house can be divided into two clear sections, separated by a continuous timber beam, or lintel that is located 2.1m above the external ground level. This timber does not extent the width of the walling to the interior, with the gable being supported on two separate beams with a void of 0.1m in between.

The upper half of the elevation comprises of a vertical brick wall that supports a mono-pitch roof with a fall towards the east (**Figure 5**). The brickwork has been built in two separate phases, with the lower using a maroon coloured brick and the upper a blue brick; measuring 22.5cm x 10cm x 8cm. The existing roof pitch is c.26 degrees, however it can be calculated that if the angle of the diagonal construction break across the elevation supported an earlier roof, its pitch would have been lower, at c.15 degrees. Set within the upper part of the brickwork at the interface of the two phases of construction, is a horizontal timber that supports a cast-iron pulley wheel and chain (**Appendix 2.6**). The chain would have operated a damper at the rear of the boilers connected to the chimney.

There is a second pulley wheel that is secured to the longer horizontal lintel and located approximately half way between the boilers. Its location, approximately lines up with an external pulley wheel attached to the eat side of the chimney (**Appendix 2.11**). Although further survey would be required to confirm this, it is possible that a chain then continued vertically from this point at the base of the chimney to the top, to operate a vent/damper.

Within the external face of the horizontal lintel are numerous compression scars from bolts, brackets, holes and fixings that have largely been removed (**Appendix 2.12**), but presumably once associated with external pipes and attachments necessary to operate the boilers. At the east end of the elevation two metal steam pipes are attached to the exterior (**Appendix 2.8**), however they have been sealed off. The pipework has been crudely inserted through the horizontal lintel and it is suggested that they are a later addition, most likely being associated with the external stationary locomotive engine that was installed in 1957 following the decommissioning of the boilers. These pipes continue along the internal face of the boiler house and would have powered the winding engine during the final years of the operation of the railway.

Above the horizontal lintel is a secondary timber that is directly attached to the brickwork above (**Appendix 2.10**). This timber is secured with large nails driven into the mortar joints. The upper edge of the timber (**Appendix 2.13**) has a series of irregularly spaced empty mortices, which are interpreted as once housing angled timbers forming rafters to support a lean-too roof (see **Appendix 1.9**). Between the mortices are projecting nails that would have supported a corrugated metal roof.

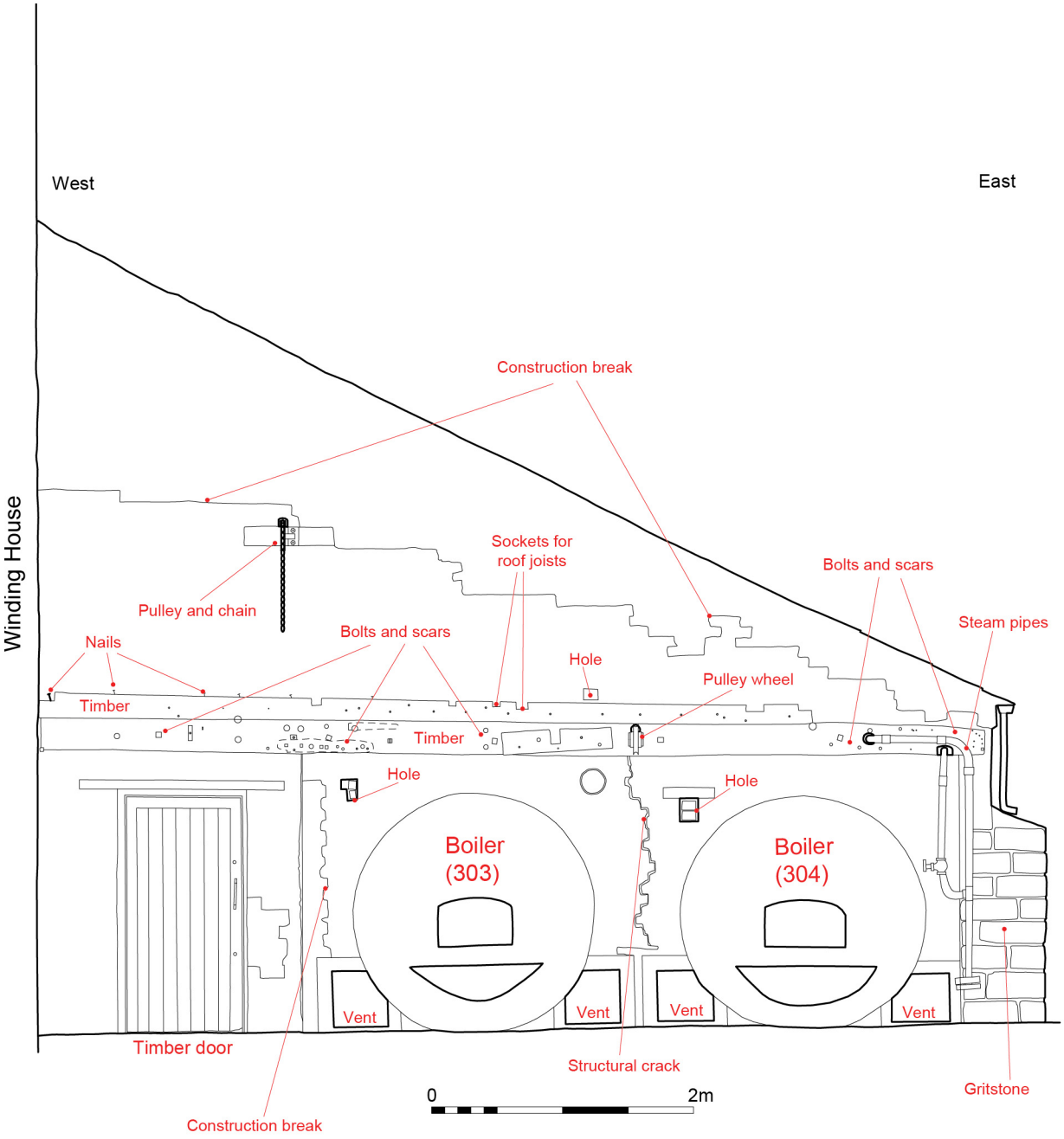


Figure 5: External north elevation of the Boiler House

The lower section of the north elevation beneath the horizontal timber lintel can be subdivided into three main parts. At the far eastern side is a 1.5m high section of gritstone walling, that pre-dates the boiler house as the brick walling is built against it and then continues above. This wall is interpreted as being part of an external yard that was attached to the winding house, perhaps containing external boilers prior to the existing ones being installed in c.1869 by the LNWR.

At the west end of the elevation forming a vertical joint with the west gable of the winding house is a vertical section of brickwork containing a plank and baton door. This door is a modern insertion, as indicated by the photograph from c.1967 (**Appendix 1.9**) and which illustrates a door made from corrugated sheeting. The surrounding brickwork comprises of alternate rows of headers and stretchers, in an orange brick measuring 2.55cm x 10.5cm x 8cm. There is a patched repair along the east side of the doorway.

The boilers are 1.85m in diameter and spaced 0.65m apart, supported upon internal brick piers. There are square cast-iron vents on either side at ground level (**Appendix 2.10**). The boilers extend the length of the building c.6.7m (22ft) in long.

Between the boilers is a section of brickwork that has a central crack 1.2cm in width (**Appendix 2.8**). This brickwork is made from alternative courses of headers and stretchers, with bricks that measure 22-23cm x 10.65cm x 7cm. This brickwork is built up to the underside of the horizontal lintel and stands proud of the upper wall face by c.10cm (see **Appendix 2.12**), indicating that it is a later insertion. This is further confirmed by two staggered vertical joints at either end of the brickwork, where bricks with rounded corners have been used. The walling represents the final phase of inspection of the boilers which occurred every six years, presumably c.1950s in date as the boilers were decommissioned in 1957.

Description of Fabric – Interior

The internal elevation (**Figure 6**) closely mirrors features and structural elements that exist externally. There is a continuous timber set into the wall, c.2m above the floor level, that would have supported the upper section of the gable to allow for the removal of the lower section of brick walling for periodic repairs and inspections of the boilers (**Appendix 2.15**). There is a small lobby at ground level, with a raised area above the boilers supported by a brick wall. Access is via a steep flight of timber steps, and the flooring between the boilers comprises of slightly cambered machine pressed red brick – 22cm x 10.5cm x 7cm with the brickworks name 'Coring…Nor'.

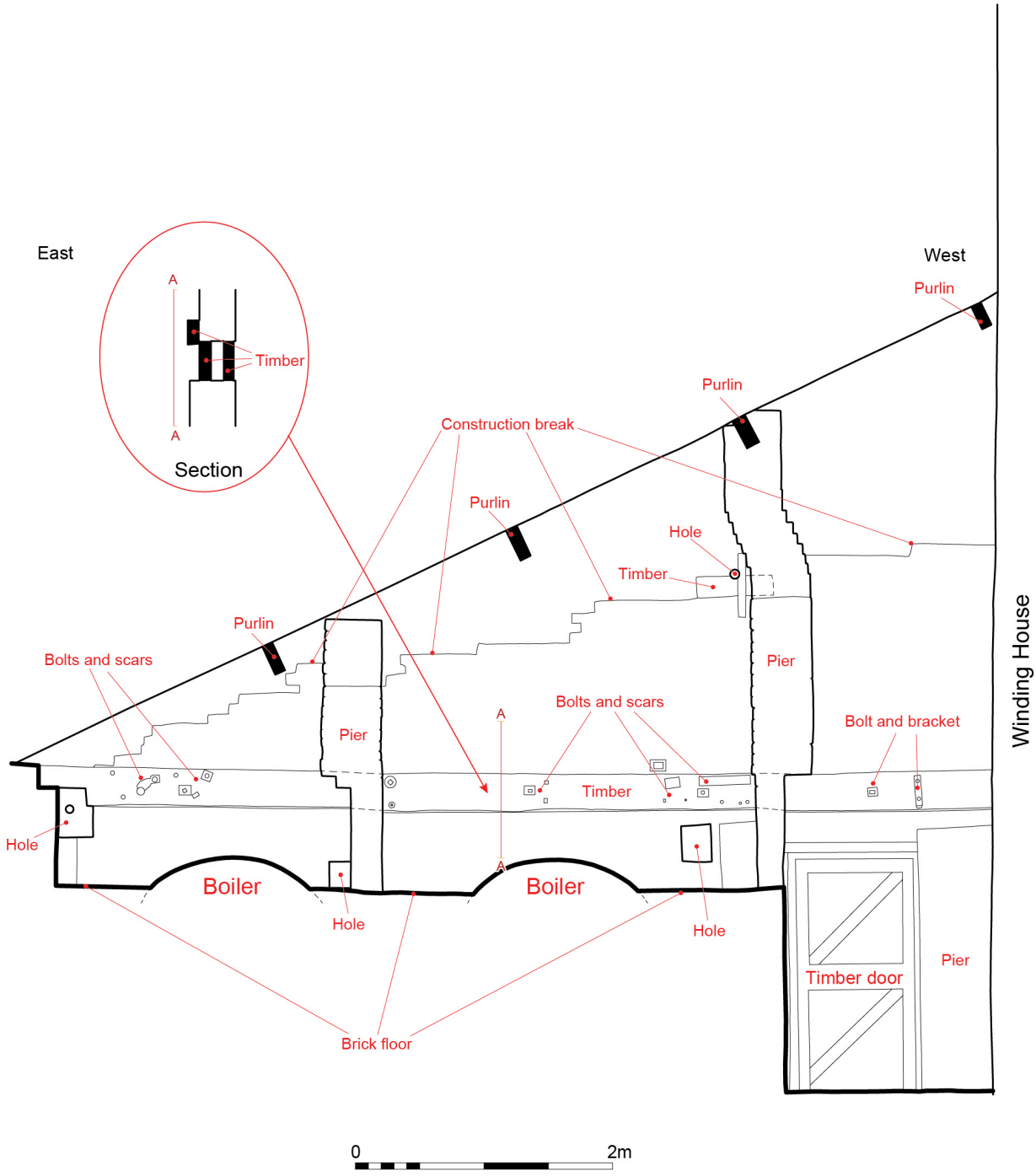


Figure 6: Internal north elevation of the Boiler House

The upper gable is internally strengthened by two vertical piers, or attached pilasters, the western has an angled upper section to provide extra support to the purlin above. This angle correlates with a diagonal construction joint in the gable representing an earlier roof pitch. The purlins all appear contemporary with the upper brickwork and it can be inferred that the existing roof dates to this phase 4 period of construction (**Appendix 2.14**).

Above the western edge of each boiler are two holes in the brickwork beneath the timber lintel, whilst their function is unclear they represent deliberate openings in the brickwork, possibly associated with removed pipes, or mechanisms to control the boilers from the exterior. At the east end of the elevation is a larger hole that has been 'knocked' into the brickwork. This contains a steam pipe that then continues along the interior of the elevation leading to the Winding House to the west. It is suggested that these pipes are associated with the transfer of steam from the stationary locomotive engine that was installed to the northwest following the decommissioning of the boilers in 1957.

The survey has confirmed that the horizontal timber lintel that supports the brickwork in the upper gable consists of two separate beams measuring 8cm x 30cm, with a 10cm void in between. This may have been to allow for the individual replacement of each timbers should repairs be necessary. The internal timber is painted black and retains evidence for fixing holes and protruding bolts largely associated with external fittings; many of which have square washers, or spacers to prevent the nut from being compressed into the timber.

Immediately above the diagonal construction break, and partially obscured behind the western brick pier, is a horizontal timber that supports an external pulley wheel and chain. This chain is understood to have operated a damper at the rear of the boilers connected to the chimney.

6 UNDERSTANDING THE SITE – MORTAR ANALYSIS

INTRODUCTION

Mortar samples were taken during this survey of the extant historic fabric that comprised the north gable of the boiler house. The samples were intended to provide a baseline understanding of the different forms of mortar that had been used to construct the elevation, and aid with the identifying of differing phases of structural alteration. The results of the sampling will also enable suitable mortar mixes to be specified during the repairs.

SAMPLING STRATEGY

Following a site meeting with Alex Gilbert and Mia Lodge of Derbyshire County Council locations were agreed for the mortar sampling. A total of eight samples were taken both internally and externally (see **Figure 7**), and which ensured that each potential phase of construction could be examined.

The samples were removed from deep within the brick joints as possible, using a hammer and cold chisel. Once removed the samples were individually bagged and labeled.

The samples taken were:

Sample 1 (external):	west side of doorway, possible phase 2 brickwork
Sample 2 (external):	within structural crack between boilers, possible phase 5 brickwork
Sample 3 (external):	surface pointing within structural crack between boilers
Sample 4 (external):	surface pointing within hole in brickwork above horizontal timber
Sample 5 (external):	brickwork above horizontal timber, possible phase 3 brickwork
Sample 6 (internal):	east side of doorway on raised brick pier, possible phase 2 brickwork
Sample 7 (internal):	brickwork above horizontal timber, possible phase 3 brickwork
Sample 8 (external):	brickwork above horizontal timber, possible phase 4 brickwork

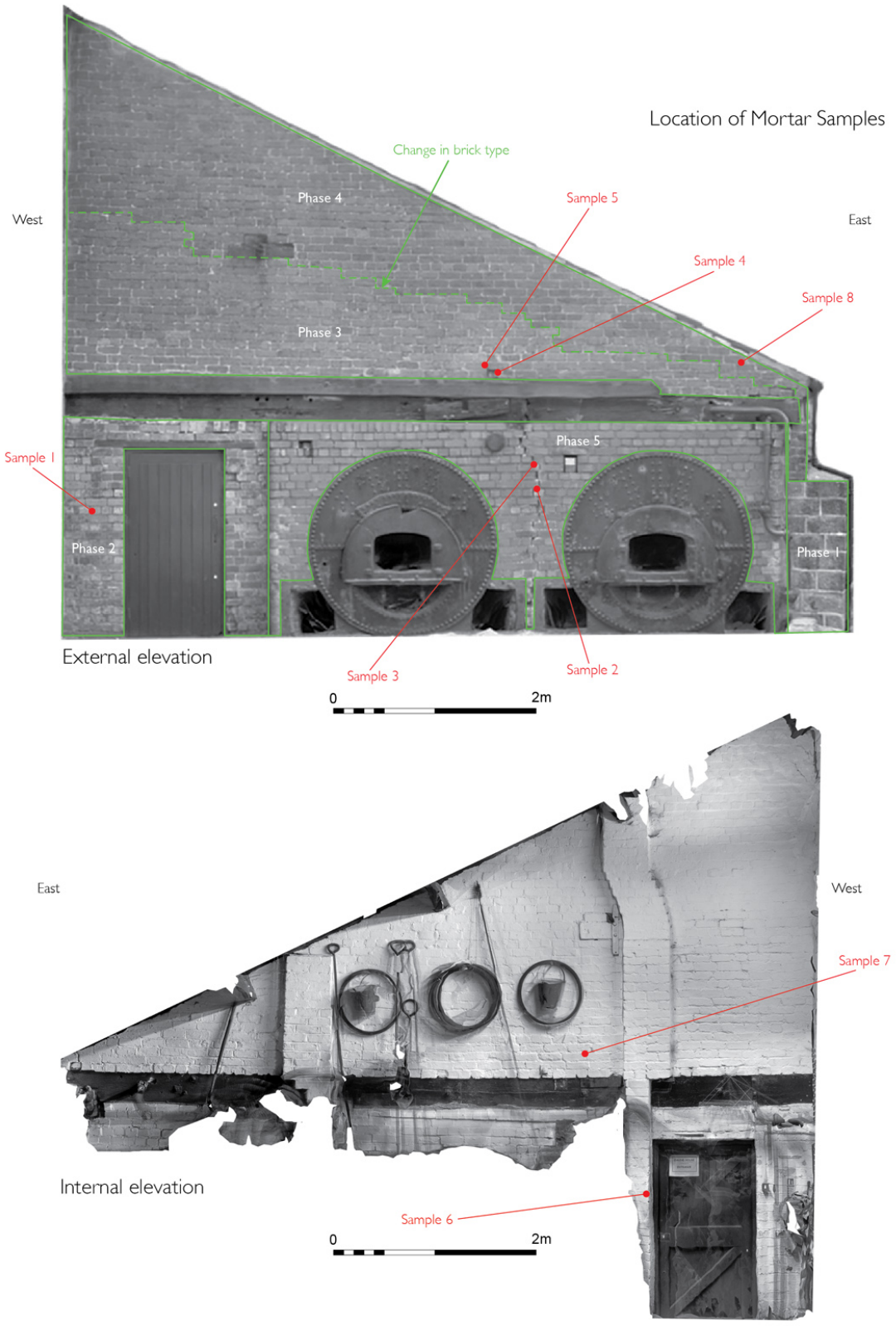


Figure 7 Location of mortar samples on external and internal elevations

Analysis

A total of six (**No's. 1,2,4,6,7,8**) out of the eight samples were deemed suitable for analysis, which was undertaken by Hirst Conservation Ltd (see **Appendix 5**). The analysis comprised of a variety of volumetric, titrimetric, gravimetric and microchemical techniques, in combination with polarized light microscopy to determine the components and characteristics of each mortar sample. Following analysis the samples were discarded.

RESULTS

The results of the analysis are detailed in **Appendix 5**, however a summary is listed below:

Sample 1:	A powdered dark grey mortar. Aggregate is a fine grained black-brown iron slag, with quartz grains. Binder is an OPC Portland cement. Mix by ratio 2.36:1 (aggregate : binder). An NHL 5 eminently hydraulic lime. Similar to samples 4, 7, 8.
Sample 2:	A very hard grey coloured dark mortar. Aggregate is a fine grained black-brown iron slag, with quartz grains. Binder is an OPC Portland cement. Mix by ratio 1.75:1 (aggregate : binder). An NHL 5 eminently hydraulic lime.
Sample 3:	No analysis undertaken (sample discarded).
Sample 4:	A powdered dark grey mortar. Aggregate is an iron slag material consisting of black-grey coke, black-brown iron oxides, with quartz grains and purple ash. Binder is an OPC Portland cement. Mix by ratio 1.86:1 (aggregate : binder). An NHL 5 eminently hydraulic lime. Similar to samples 1, 7, 8.
Sample 5:	No analysis undertaken (sample discarded).
Sample 6:	A powdered buff coloured mortar. Aggregate mainly comprises of quartz grains, sand and ash. The binder is equivalent in strength to an NHL3.5 moderately hydraulic lime. Mix by ratio 0.8:1 (aggregate : binder). An NHL 3.5 a moderately hydraulic lime.
Sample 7:	A powdered dark grey mortar. Aggregate is an black-brown iron slag material, with quartz grains. Binder is an OPC Portland cement. Mix by ratio 1.9:1 (aggregate : binder). An NHL 5 eminently hydraulic lime. Similar to samples 1, 4, 8.
Sample 8:	A powdered dark grey mortar. Aggregate is an black-brown iron slag material, with quartz grains. Binder is an OPC Portland cement. Mix by ratio 2.2:1 (aggregate : binder). An NHL 5 eminently hydraulic lime. Similar to samples 1, 4, 7.

DISCUSSION – MORTAR ANALYSIS

The results of the mortar analysis have identified that all six samples having differing compositions, although samples **1, 4, 7** and **8** have similar quantities of a fine grained iron slag with quartz grains. They are all classed as being an NHL 5 strength, which makes them a hydraulic lime mix that is suitable for external work in exposed areas, such as chimneys, or structural elements that require considerable strength such as floor slabs, or underpinning.

Samples **4** and **7** were taken on opposite sides of the brick walling (internal and external faces) immediately above the horizontal timbers set within the wall.

The section of external brickwork between the two projecting boilers (sample **2**) that has been classified as being associated with re-building work in phase 5, is also a hard NHL 5 mortar that is grey in colour and contains iron slag and quartz grains.

Sample **6** which was taken from the internal pier to the eat of the doorway, was found to be notable different in composition and colour to the others. It had a lower strength (NHL 3.5), but is still suitable for internal and external uses.

The differences within each sample does broadly correlate with the five phases of construction that have been identified within the stratigraphy that forms the north wall of the boiler house, and that the builders appear to have made use of locally sourced materials including furnace slag, coke, sand and ash for the mortar. These compositions are typical for industrial structures from the first half of the 19th century.

RECOMMENDATIONS

During the rebuilding of the brickwork that forms the upper part of the gable and in-between the projected ends of the boilers, the analysis of the mortar samples indicates that a hydraulic mortar mix which has a strength of NHL 5 would be appropriate for any repairs. This may be coloured, depending upon where in the brickwork it is located. Externally, a grey colour is prevalent, whilst internally, the lower part of the wall has a buff composition.

7 DISCUSSION AND RECOMMENDATIONS

DISCUSSION

This archaeological survey of the north wall of the boiler house at Middleton Top has identified five principal phases of construction, with a sixth representing the decommissioning of the railway in after 1967.

The architectural form of the building is functional, consistent with contemporary boiler houses elsewhere from the 19th century, which would have required a simple, relatively lightweight building to cover and protect the boilers from the weather. This would have allowed them to maintain a constant temperature and also provide limited protection from the men who would be operating them.

The upper brick walling is supported upon a long horizontal timber lintel, which effectively formed a large self supported opening above the two boilers (**Appendix 2.10**). This was necessary to allow for the periodic (every six years) inspection of the boilers for repair and maintenance. The opening was then bricked up, which may explain the large structural crack within this brickwork as it was never intended to last for a significant length of time.

The empty mortices and surviving nails protruding from the upper edge of the attached timber on the external elevation (**Appendix 2.13**) are all associated with a former lean-to roof that protected the mouths of the boilers. A photograph taken at the time of closure of the railway in c.1967 (**Appendix 1.9**) confirms that there was a simple pitched roof in this location covered with corrugated metal sheeting. In addition, there was a timber doorway to the east of the boilers and the remnants of a side wall covered with metal sheeting. Even a simple enclosure such as this, would have been effective at keeping the snow and inclement weather away from the boilers, necessary as the railway operated throughout the year. The enclosure may also have been used as a fuel store for the wood to power the boilers.

The confirmation that the upper gable is supported upon two separate timbers is interesting, and may indicate that repairs of the timbers were anticipated and they could then be replaced independently rather than having to dismantle the whole gable above.

RECOMMENDATIONS

1. Resulting from the mortar analysis, it is recommended that during the rebuilding of the brickwork that forms the upper part of the gable, a hydraulic mortar mix which has a strength of NHL 5 would be appropriate. This may be coloured, depending upon where in the brickwork it is located. Externally, a grey colour is prevalent, whilst internally the lower part of the wall has a buff composition;

2. Consideration should also be give to reinstating a lean-to roof above the two boilers, a feature that has only been removed since the closure of the railway. This would help visitors understanding of the former operation of the building and enhance the visual integrity of the north elevation;

3. This survey has focused upon the north wall of the boiler house, and it is recommended that should funds become available that a survey of the remainder of the structure is undertaken to create a comprehensive recording of the building which is an important part of the Scheduled Monument;

4. During any ground disturbance works or dismantling of the gable, an intermittent archaeological watching brief is recommended to document aspects of the boiler house that are currently obscured or inaccessible. This should be undertaken by a suitably experienced archaeologist who is a member of the Chartered Institute for Archaeologists.

8 SUPPORTING INFORMATION

AUTHORSHIP

This report has been prepared by Oliver Jessop MCIfA and graphics were produced by Ian Atkins MCIfA. Editing has been provided by Manda Forster PhD MCIfA.

ACKNOWLEDGEMENTS

Mia Lodge and Alex Gilbert of Derbyshire County Council provided survey drawings for the project and access to archive records held by the County Council, and their patience during the survey is acknowledged. Tim Allen of Historic England is thanked for discussing the development of the building and for providing access to case files for the monument.

The staff at the Derbyshire record office and local studies libraries are thanked for locating historical reference material.

Rick Jillings and his team at Middleton Top are thanked for their help during the fieldwork and for sharing their knowledge regarding the former use of the boiler house.

PROJECT ARCHIVE

The fieldwork archive has been deposited with the Derbyshire Record Office (September 2016). *Its contents include:*

- Copy of final report (TJC2016.40)
- Background research papers (x24 A4 pages)
- 1x b/w photographic negative sheets (Films 1)
- b/w photographic prints (x13 10x8)
- colour print (x1 8x6)
- Permatrace field drawings (2x A3)
- Mortar analysis (inc. Results) (9x A4)

SOURCES AND REFERENCES CONSULTED

PRIMARY SOURCES CONSULTED: VISUAL RECORDS

- Ordnance Survey maps 1880, 1899, 1922, 1968, 1977, 2016
- British Geological Map of Britain (digital data), 2016

SECONDARY SOURCES: PUBLISHED WORKS AND GREY LITERATURE

Baxter, B. 1949. 'Early railways in Derbyshire', *Engineering*. Vol. 167, pp 573-576.

Blakemore, M & Mosley, D. 2003. *Railways of the Peak District*. p. 45.

Rimmer, A. 1998. *The Cromford and High Peak Railway*. p. 13, 32-34, 42-43, 10

CIfA (Chartered Institute for Archaeologists). 2014. *Standards and Guidance for the archaeological investigation and recording of standing buildings and structures*. Chartered Institute for Archaeologists: Reading

Fowkes, D. eds., 1986. *Derbyshire Archaeology: A Gazetter of Sites.* Derbyshire Archaeological Society

HE (Historic England). 2016. *Understanding Historic Buildings: a guide to good recording practice*. Historic England: London

Jessop, O. 2003. *Cromford & High Peak Railway and Peak Forest Tramway Survey*. ARCUS 738b. Feature number: 113

Jones, N & Bentley, M. 2000. *Scenes from the Past: 37 (Part One) Railways of the High Peak. 'Whaley Bridge to Friden*'. p. 27-28

Marshall, J. 1996. *The Cromford & High Peak Railway*. p. 14,15, 40, 50, 85, 96

Morris, R. 2003. *The Archaeology of Railways*. p. 62

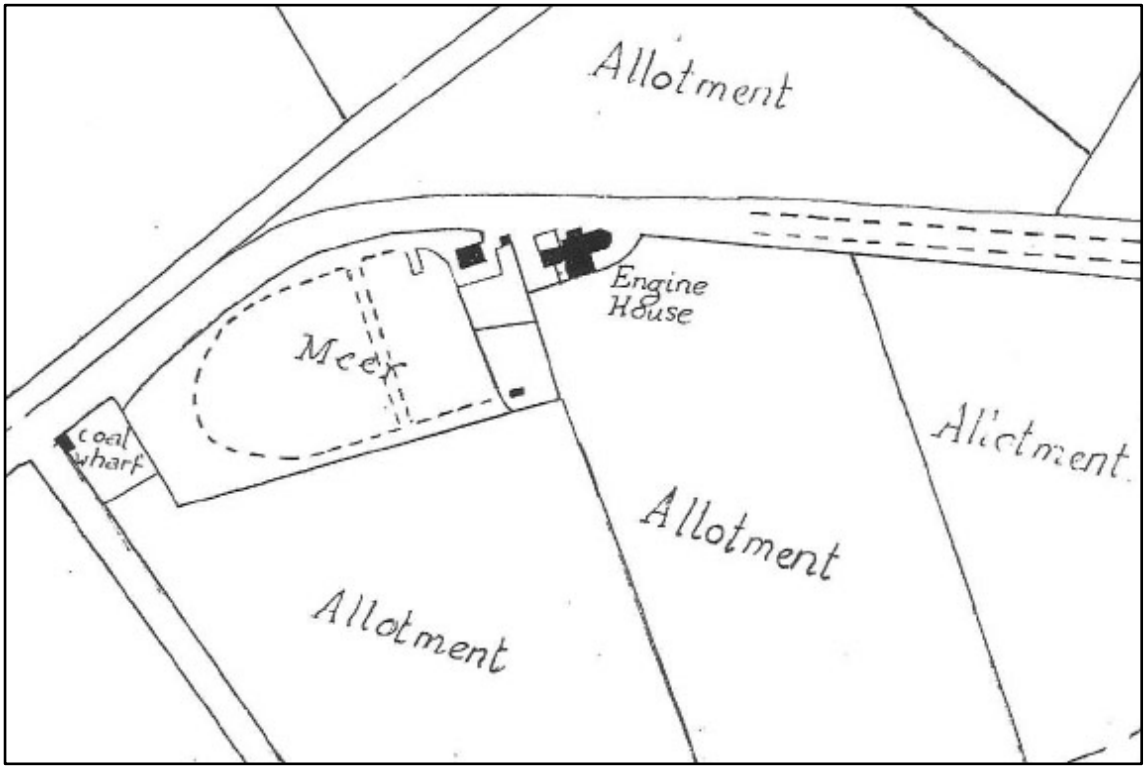
Nixon, F. 1969. *The Industrial Archaeology of Derbyshire*. David and Charles, Newton Abbot, p. 117, 156, 117

INTERNET RESOURCES

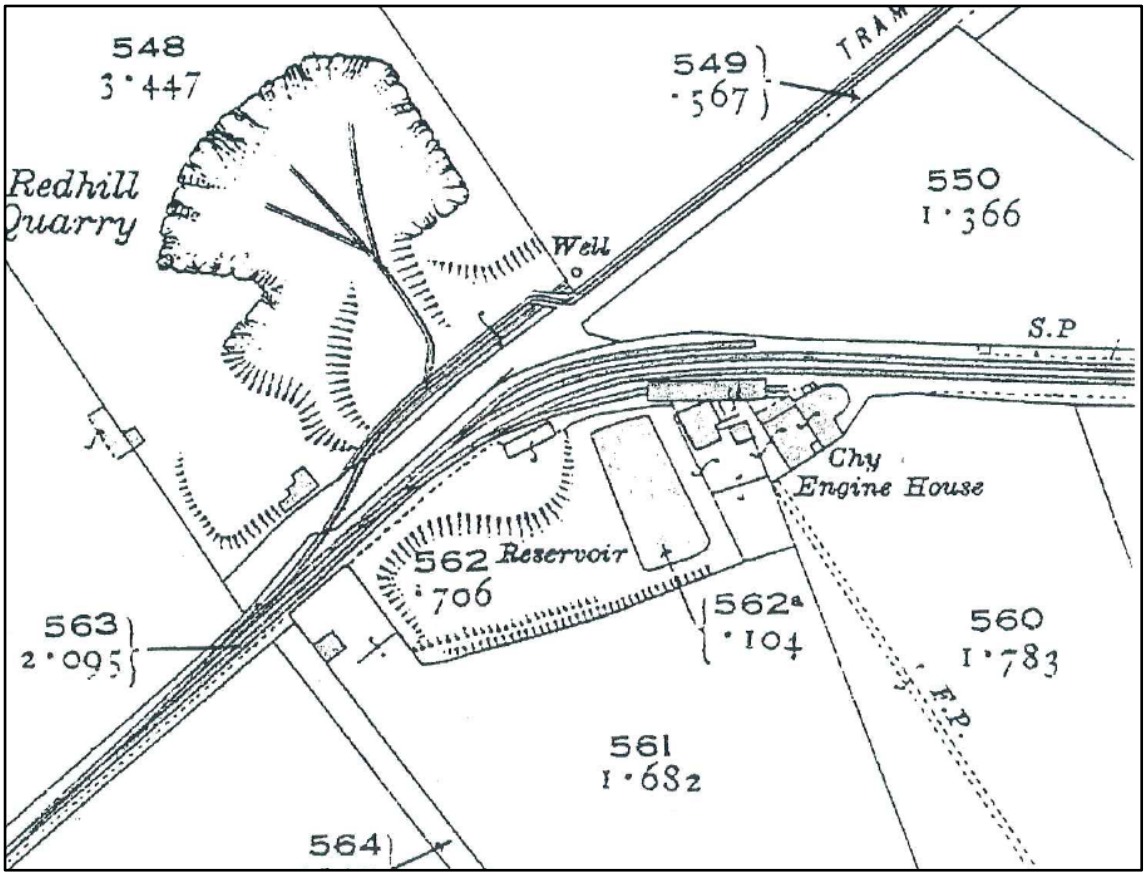
- ADS: www.archaeologydataservice.ac.uk
- British Geological Survey: www.bgs.ac.uk
- Heritage Gateway: www.heritagegateway.org.uk
- National Archives: www.discovery.nationalarchives.gov.uk
- National Heritage List: www.english-eritage.org.uk/professional/protection/process/national-heritage-list-for-england/

Appendix 1:

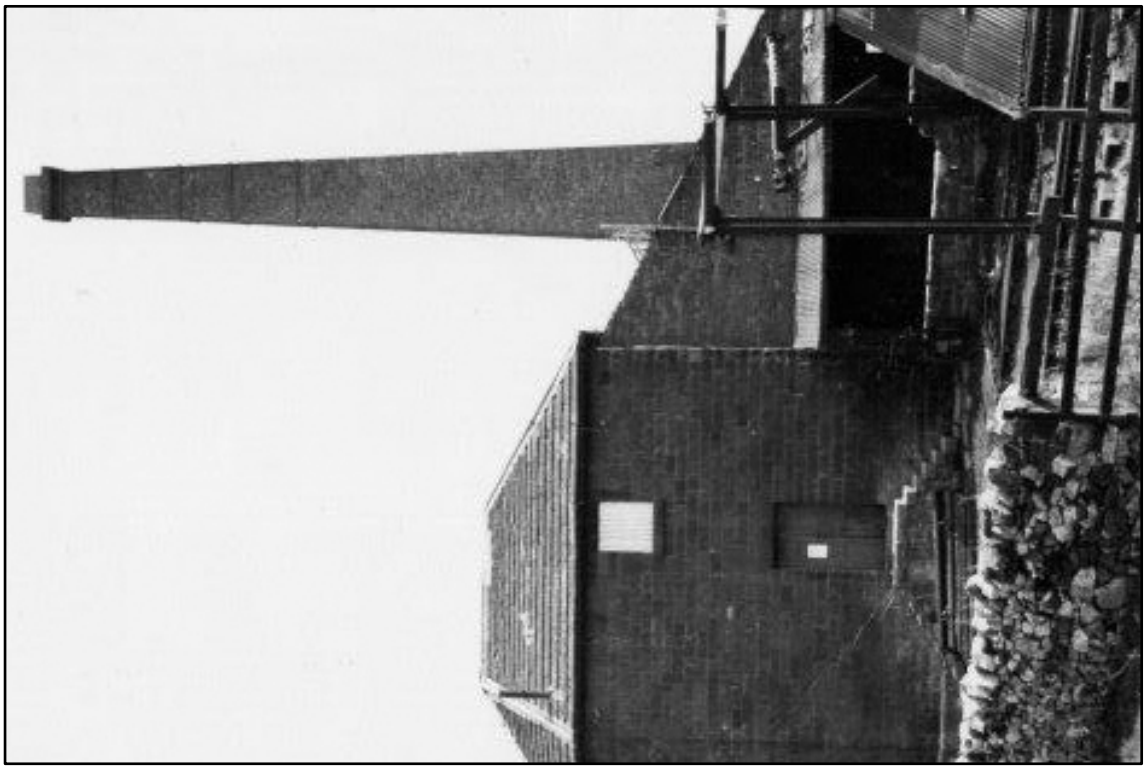
Historic sources: mapping, illustrations and photographs



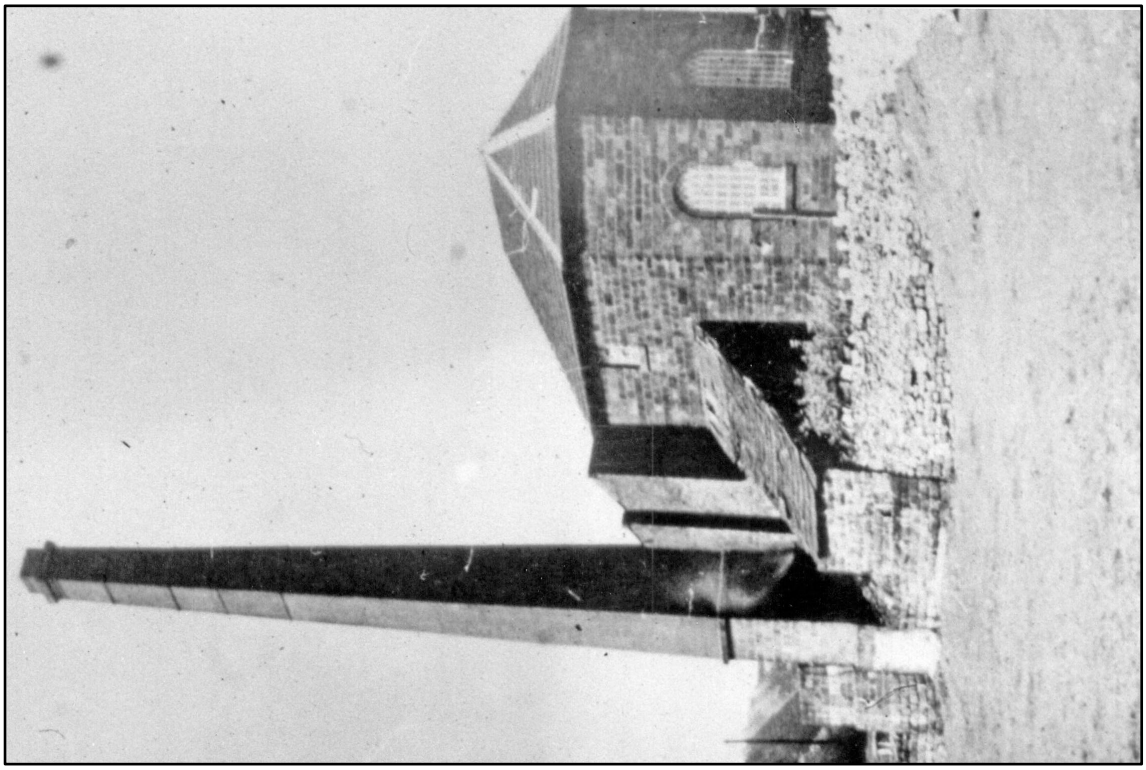
Appendix 1.1: Extract from Tithe Map1848



Appendix 1.2: Extract from 1922 edition Ordnance Survey map



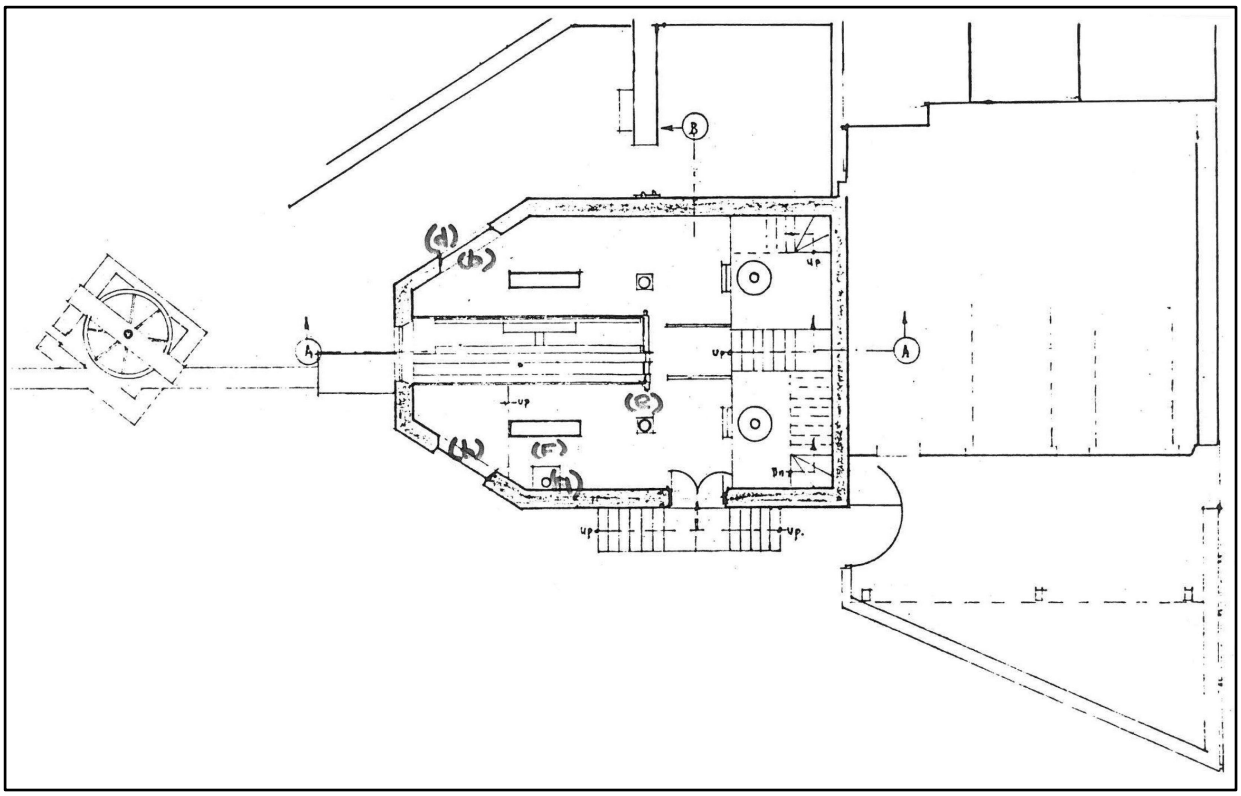
Appendix 1.3: Early 20th century photograph of Winding House and Boiler House; note lean-to roof



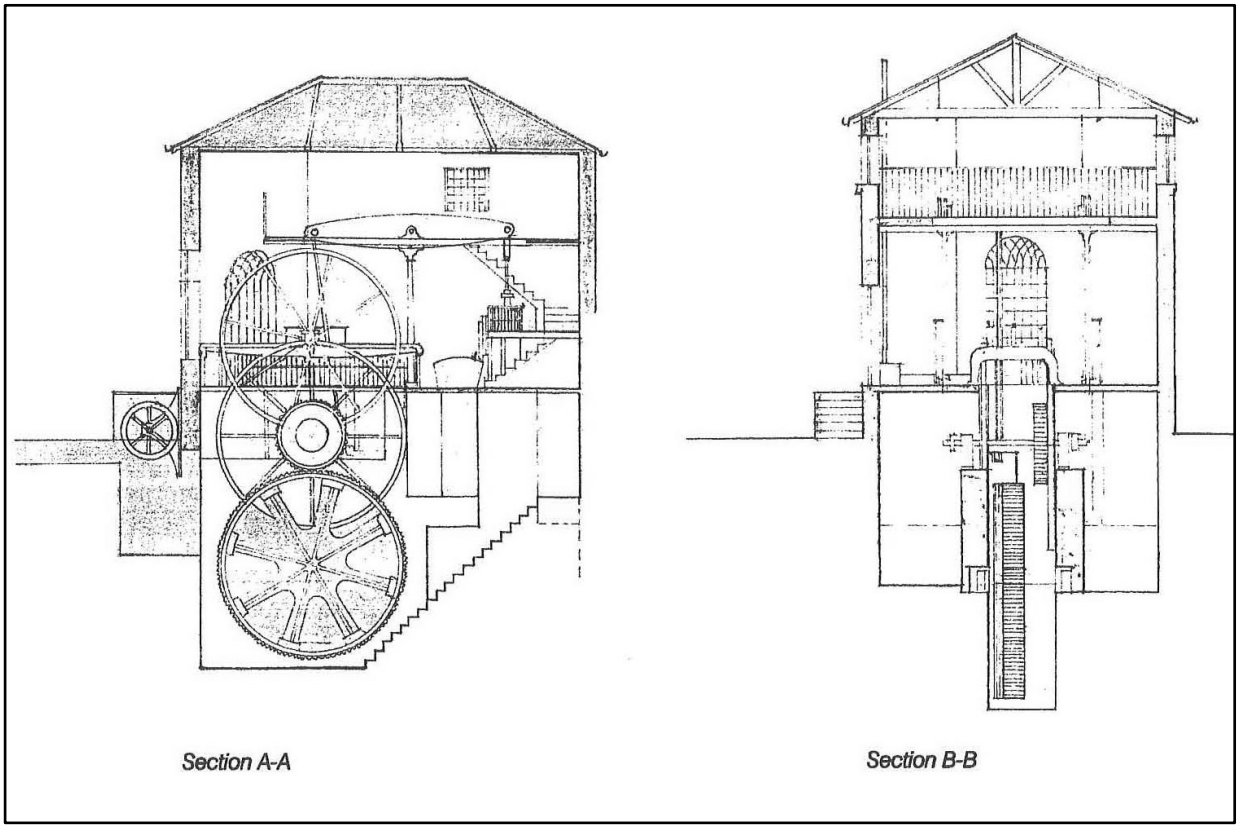
Appendix 1.4: Early 20th century photograph of Winding House and Chimney

Appendix 1.5: 1960s photograph of engine shed and fixed steam engine to the west of boiler house

Appendix 1.6: 1960s photograph of winding house and fixed steam engine to provide steam power



Appendix 1.7: Plan of Winding House and Boiler House by the Derbyshire Archaeology Society, c.1980s



Appendix 1.8: Sections through Winding House by the Derbyshire Archaeology Society, c.1980s

Appendix 1.9: Photograph c.1960s of Boiler House; note lean-to roof

Appendix 2:
Site Photographs

Appendix 2.1: General view of external elevation from top of incline, looking southwest (3m scale). **Film 1.2**.

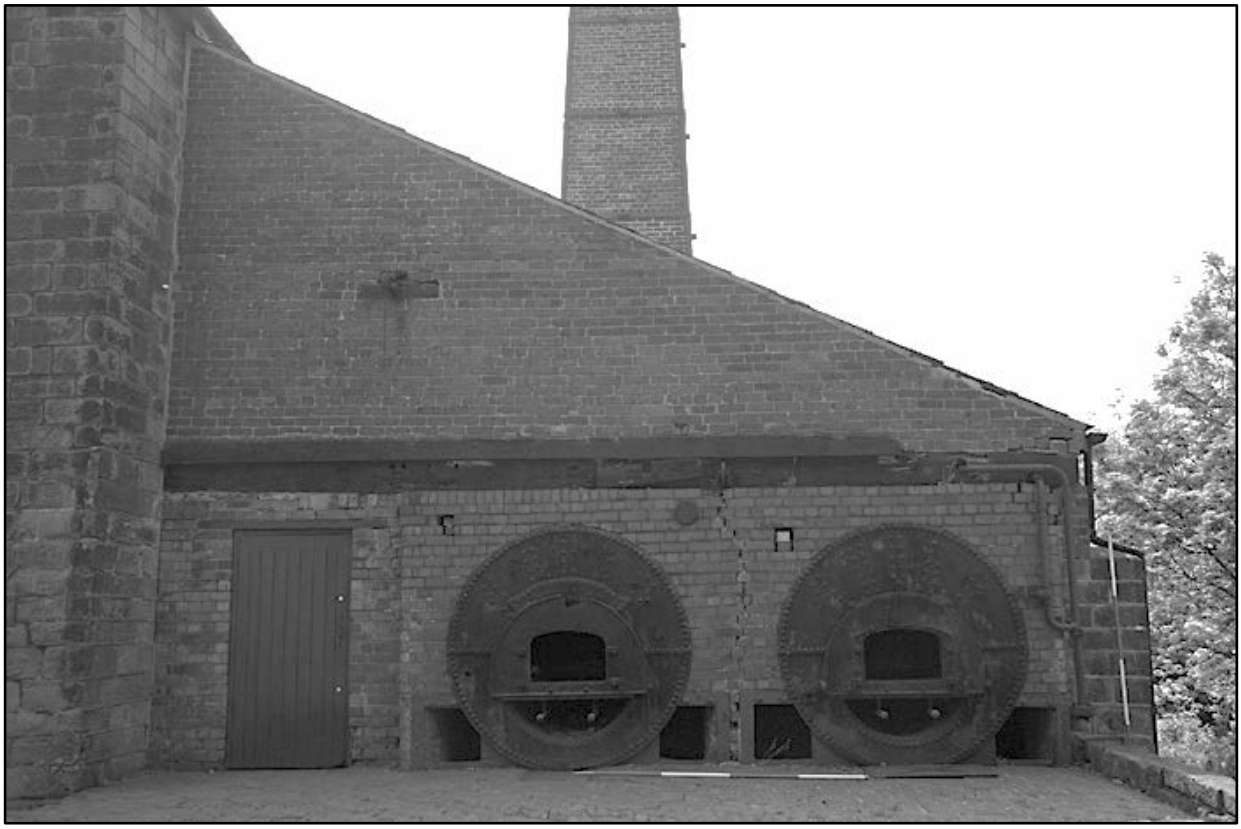
Appendix 2.2: General view of south elevation, looking northwest (3m scale). **Film 1.6**.

Appendix 2.3: Detail of south side of Winding House and Chimney, looking southwest (3m scale). **Film 1.3**.

Appendix 2.4: General view of south elevation and chimney, looking northwest (3m scale). **Film 1.9**.

Appendix 2.5: General view of south elevation and chimney, looking northeast (3m scale). **Film 1.12**.

Appendix 2.6: Detail of wheel (for possible damper) on southwest side of chimney. **Film 1.14**.

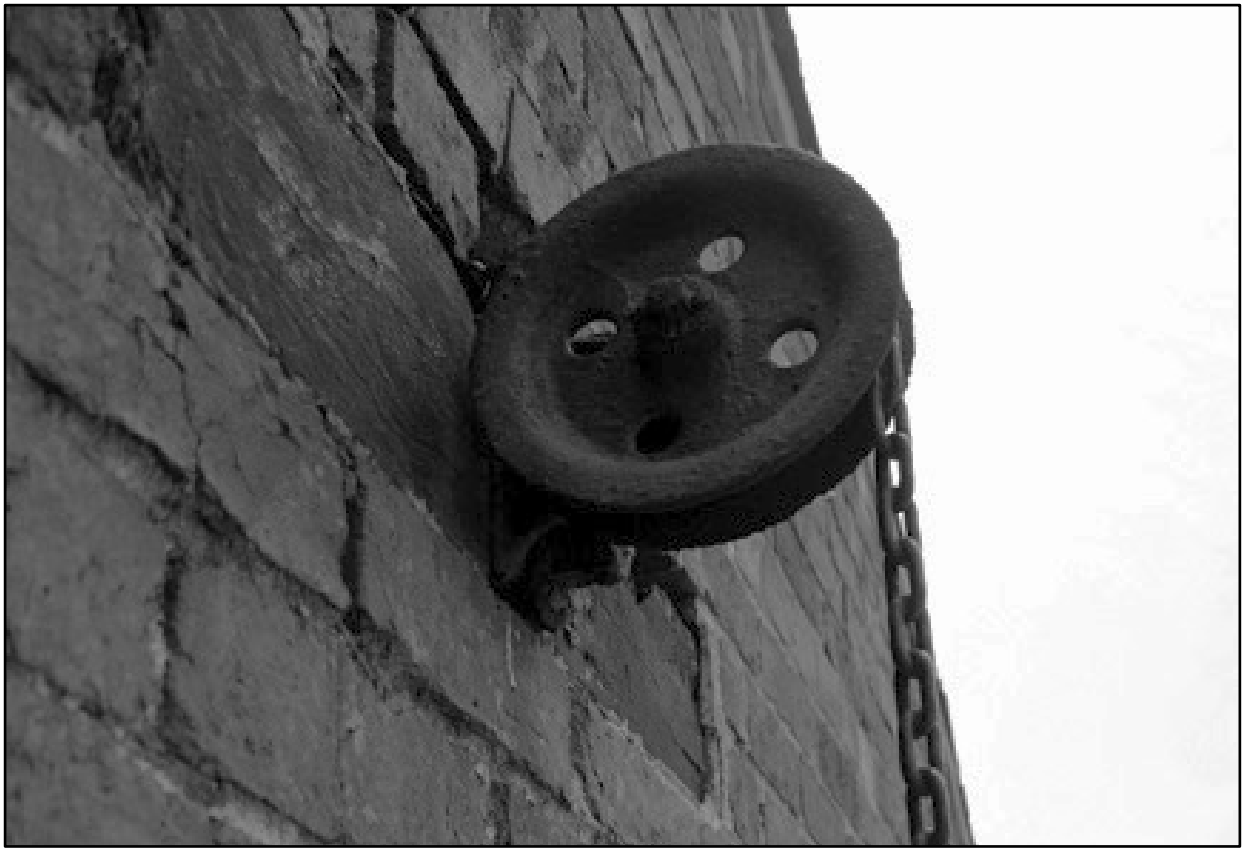


Appendix 2.7: General view of north elevation, looking south (2m scale). **Film 1.20**.

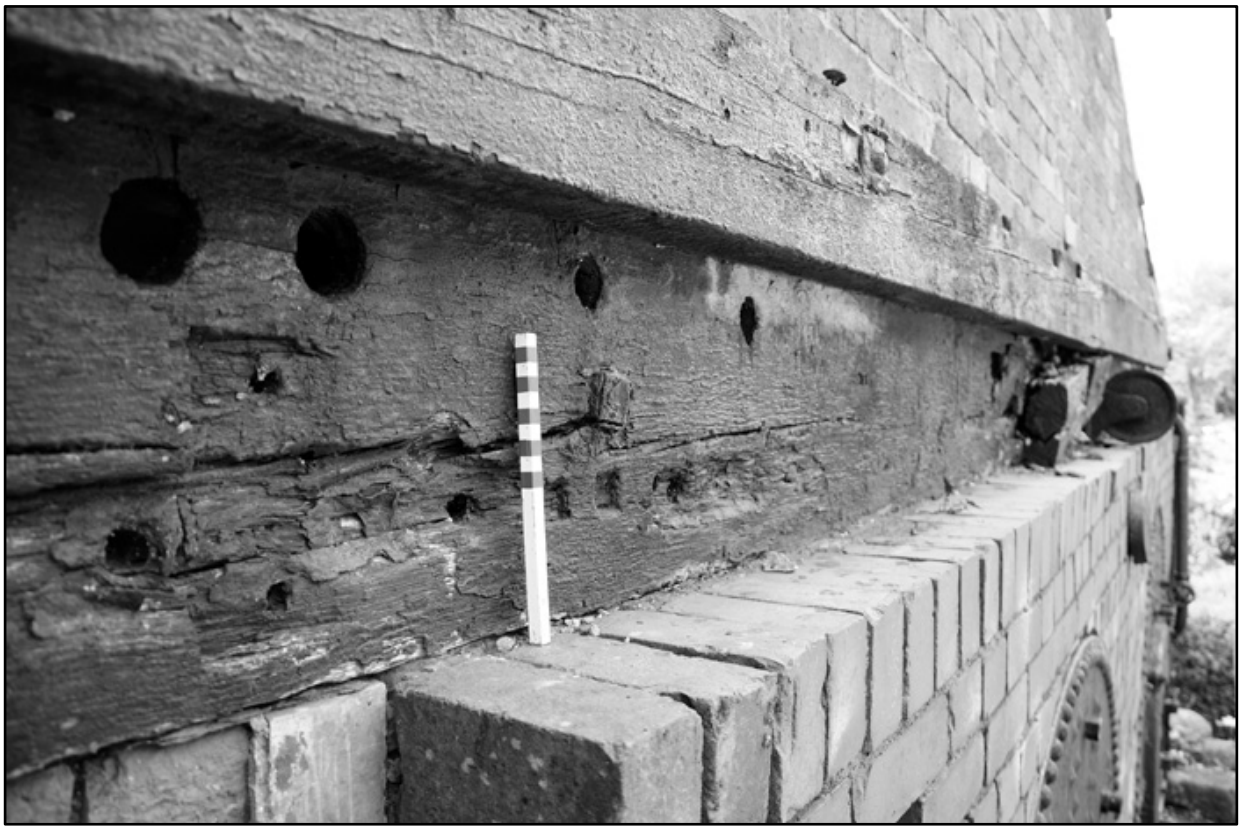
Appendix 2.8: Detail of north elevation, looking south; note structural crack and timber lintel. **Film 1.23**.

Appendix 2.9: General view of north elevation, looking southwest (2m scale). **Film 1.24**.

Appendix 2.10: Detail of north elevation, looking southwest; note boilers with brick walling (2m scale). **Film 1.27**.

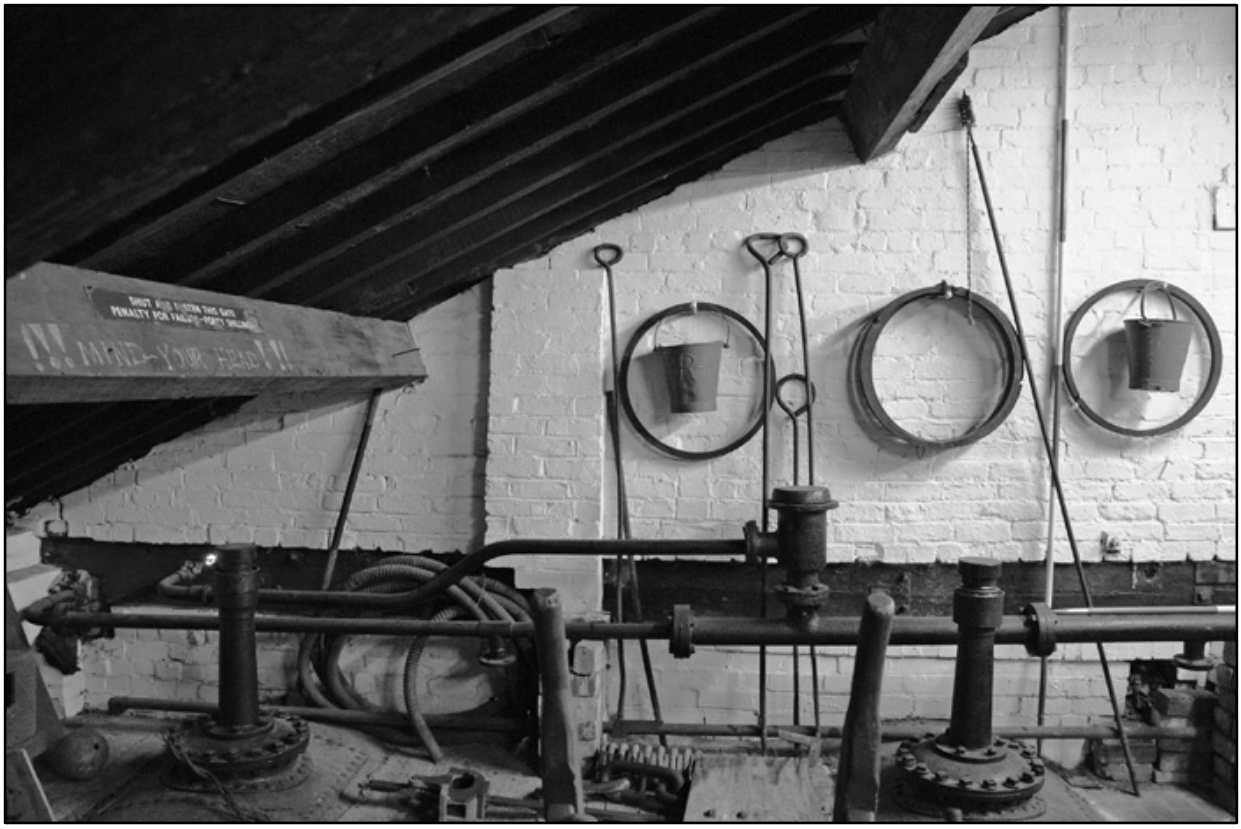


Appendix 2.11: Detail of pulley wheel above boilers in gable of north elevation.

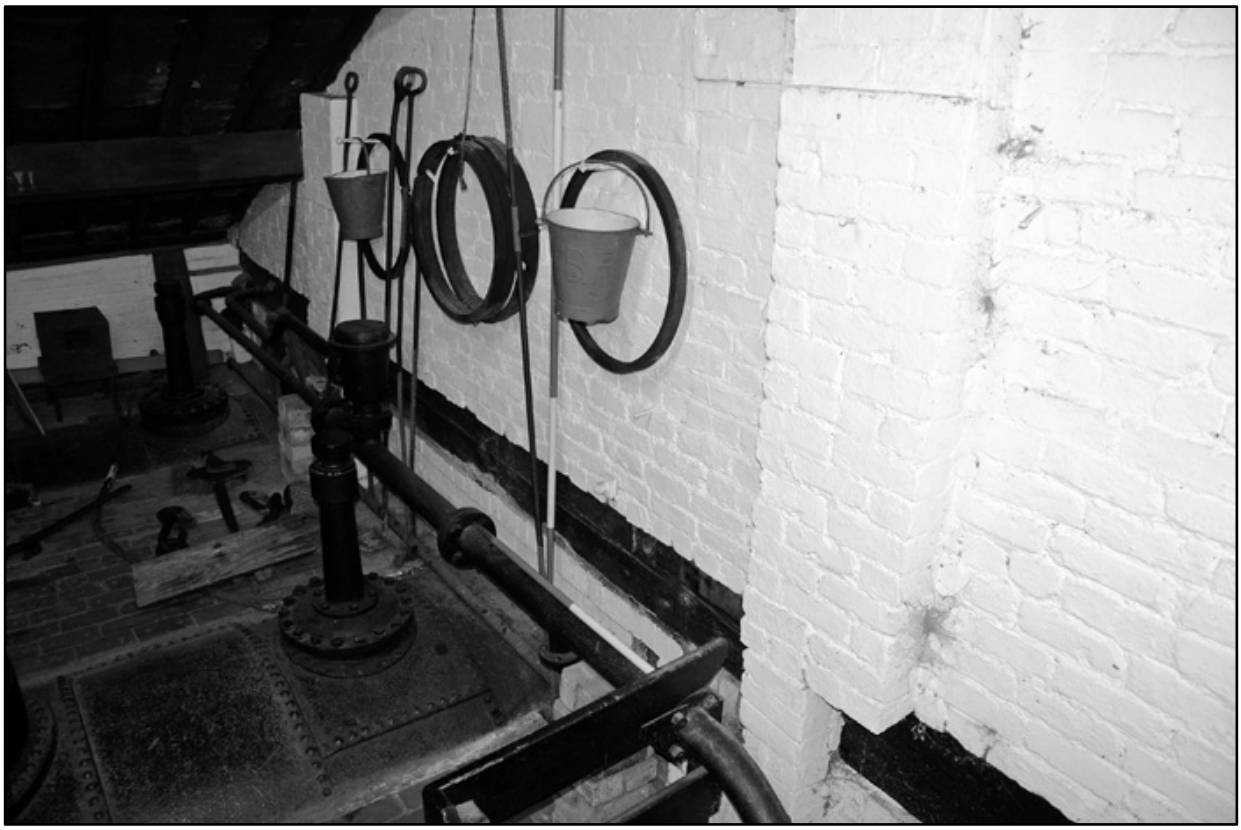


Appendix 2.12: Detail of timber beam along north elevation; note compression scars and bolt holes (20cm scale). **Film 1.30**.

Appendix 2.13: Detail of timber beam along north elevation from above; note empty slots for roof joists (20cm scale). **Film 1.29**.



Appendix 2.14: General view of internal elevation, looking north (3m scale). **Film 1.31**.



Appendix 2.15: General view of internal elevation, looking northwest (3m scale). **Film 1.34**.

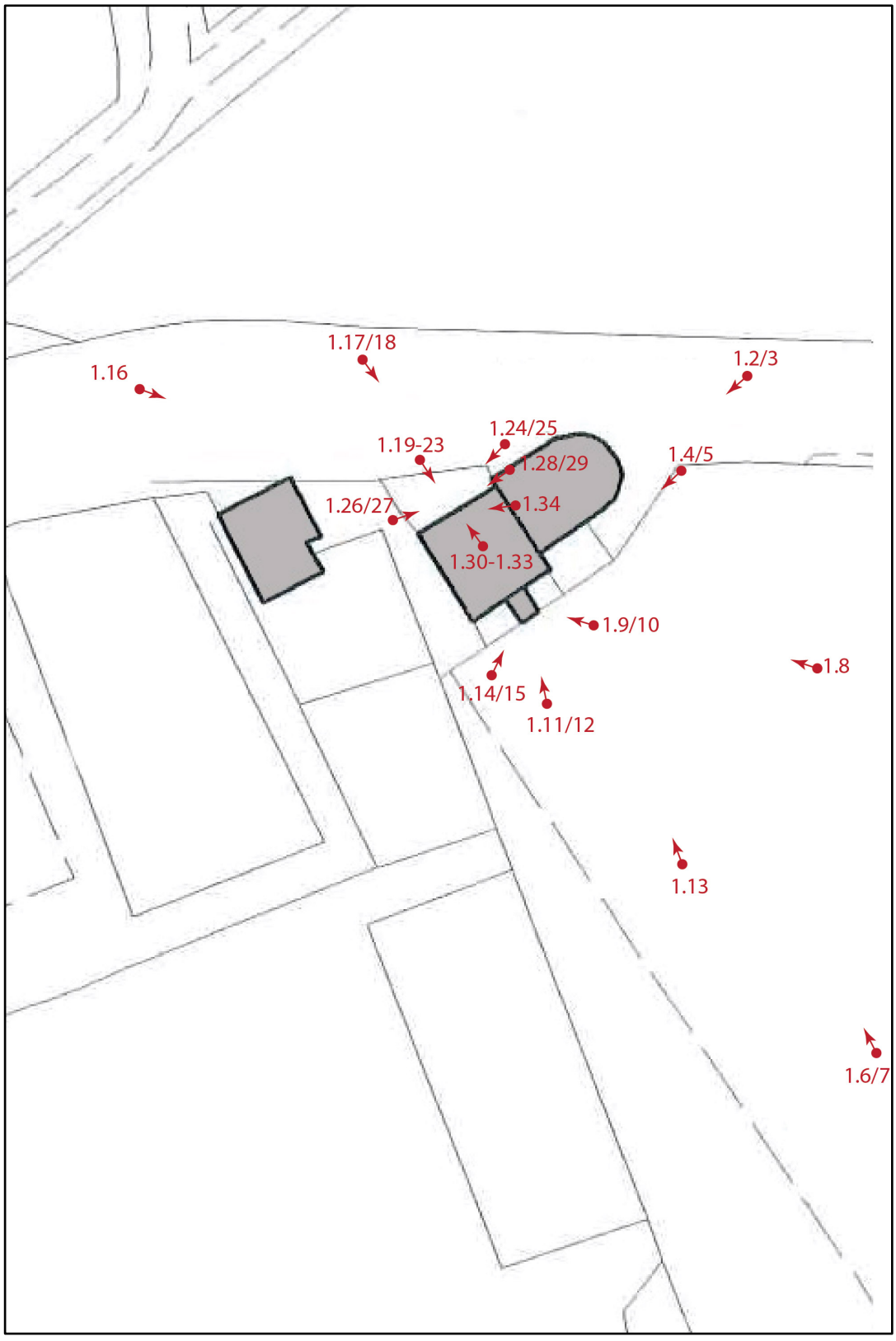
Appendix 3:

Photographic register and viewpoint plan

Film 1: b/w 35mm

Frame	Appendix	Description	Scale	Direction	Date
1.1	------	I D Shot	------	------	09.06.16
1.2	**2.1**	General view of exterior from top of incline	3m	SW	09.06.16
1.3	**2.3**	General view of exterior from top of incline	3m	SW	09.06.16
1.4		Detail of south side fo engine house	3m	SW	09.06.16
1.5		Detail of south side of engine house	3m	SW	09.06.16
1.6	**2.2**	General view of south elevation	3m	NW	09.06.16
1.7		General view of south elevation	3m	NW	09.06.16
1.8		General view of south elevation	3m	W	09.06.16
1.9	**2.4**	Detail of chimney and south elevation	3m	NW	09.06.16
1.10		Detail of chimney and south elevation	3m	NW	09.06.16
1.11		Detail of chimney and south elevation	3m	NW	09.06.16
1.12	**2.5**	Detail of chimney and south elevation	3m	NW	09.06.16
1.13		Detail of chimney and south elevation	3m	NW	09.06.16
1.14	**2.6**	Detail of chimney and south elevation	3m	NE	09.06.16
1.15		Detail of chimney and south elevation	------	NE	09.06.16
1.16		General view of boiler house	2m	SE	09.06.16
1.17		General view of north elevation of boiler house	2m	SE	09.06.16
1.18		General view of north elevation of boiler house	2m	SE	09.06.16
1.19		Detail of north elevation of boiler house	2m	SE	09.06.16
1.20	**2.7**	Detail of north elevation of boiler house	2m	SE	09.06.16
1.21		Detail of north elevation of boiler house	2m	SE	09.06.16
1.22		Detail of north elevation of boiler house	2m	SE	09.06.16
1.23	**2.8**	Detail of north elevation of boiler house	2m	SE	09.06.16
1.24	**2.9**	Detail of boilers in north elevation	2m	SW	09.06.16
1.25		Detail of boilers in north elevation	2m	SW	09.06.16
1.26		Detail of boilers in north elevation	2m	NE	09.06.16
1.27	**2.10**	Detail of boilers in north elevation	2m	NE	09.06.16
1.28		Detail of timber beam in north elevation	20cm	SW	09.06.16
1.29	**2.13**	Detail of timber beam in north elevation	20cm	SW	09.06.16
1.30	**2.12**	General view of interior of north wall of boiler house	2m	NW	09.06.16
1.31	**2.1**	General view of interior of north wall of boiler house	2m	NW	09.06.16
1.32		General view of interior of north wall of boiler house	2m	NW	09.06.16
1.33		General view of interior of north wall of boiler house	2m	NW	09.06.16
1.34	**2.15**	General view of interior of north wall of boiler house	2m	SW	09.06.16
1.35	------	Void	------	------	------
1.36	------	Void	------	------	------
1.37	------	Void	------	------	------

Photographic viewpoints



Appendix 4:

Scheduled Monument description – NHLE: 1007038

Middleton Top winding engine house, wheels and wheel-pit

List Entry Summary
This monument is scheduled under the Ancient Monuments and Archaeological Areas Act 1979 as amended as it appears to the Secretary of State to be of national importance. This entry is a copy, the original is held by the Department for Culture, Media and Sport.

Name: Middleton Top winding engine house, wheels and wheel-pit
List entry Number: 1007038
Location: Not currently available for this entry.

The monument may lie within the boundary of more than one authority.
County: Derbyshire
District: Derbyshire Dales
District Type: District Authority
Parish: Middleton
National Park: Not applicable to this List entry.
Grade: Not applicable to this List entry.
Date first scheduled: N/A
Date of most recent amendment: N/A

Legacy System Information
The contents of this record have been generated from a legacy data system.

Legacy System: RSM - OCN
UID: DR 180

Asset Groupings
This list entry does not comprise part of an Asset Grouping. Asset Groupings are not part of the official record but are added later for information.

List entry Description
Summary of Monument
Not currently available for this entry.
Reasons for Designation
Not currently available for this entry.

History
Not currently available for this entry.

Details
This record has been generated from an "old county number" (OCN) scheduling record. These are monuments that were not reviewed under the Monuments Protection Programme and are some of our oldest designation records. As such they do not yet have the full descriptions of their modernised counterparts available. Please contact us if you would like further information.
Selected Sources

Legacy Record - This information may be included in the List Entry Details

National Grid Reference: SK 27599 55177

Appendix 5:

Results of mortar analysis

Head Office:

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HIRST Conservation

London Office:

75 Cowcross Street
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EC1M 6EL
Tel: 0800 068 5418
Website: www.hirst-conservation.com

Mortar Analysis

Date Analysed: 26th July 2016

Sample: 1, South facing external Boiler House wall (phase 2 brickwork), Middleton Top Engine House, Derbyshire.

Observations: A now powdered, dark grey coloured mortar.

RESULTS

Components of Mortar	Method	Results % by mass	
Calcium Carbonate %C	Calcimetry - CO_2 emission	**11.59**	
Dolomite %D	Calcimetry and titrimetric (EDTA)	**0**	
Aggregate	Gravimetric	**77.05**	
Gypsum	Barium Chloride	**0.904**	
Nitrates	Titrimetric/test strips.	**0.01**	
Chlorides	Titrimetric/test strips.	**0.16**	
Iron Oxides (Fe_2O_3)	Test strips/Titrimetric (potassium dichromate)	**0.6**	
pH of mortar sample	Indicator Strips/pH meter	**7**	
Mix Ratio	**Parts By Mass Aggregate : Binder (A : B)**	**3.38**	
Mix Ratio if binder was lime putty	**Parts By Volume Aggregate : lime putty**	**1.96**	
Mix Ratio if binder was HL/cement	**Parts By Volume Aggregate : Hydraulic Lime or cement**	**2.36**	
Active lime [$Ca(OH)_2$]	Titrimetric (Extracted in 10% sugar solution)	**0**	
Carbonated lime in binder (degree of Carbonation)	From %$Ca(OH)_2$ in binder	**100**	
Cementitious Compounds	%S x 2.5	**9.67**	
Soluble Silica %S	Volumetric/Titrimetric - (Conversion to silicomolybdic acid)	**3.86**	
Soluble Silica in Original Binder	From %S x $(\frac{A}{B} + 1)$	**22.55**	
CaO in Original Binder	From CaO in mortar	**68.73**	
CaO in Mortar	Titrimetric (EDTA) Gravimetric (ammonium oxalate)	**11.78**	
Aluminium Oxide in Binder	Gravimetric (using Oxine)	**-**	
Cementation Index for Binder (CI)	CI ≈ $\frac{\%S \times 2.5}{(\%C \times 0.56) + (\%D \times 1.5)}$	**1.41**	
Type of Binder	Dependent on the % Soluble Silica in Binder	**Cement**	

A lime putty with 50% moisture by mass is considered in the calculations above.A greater percentage of moisture in the lime putty, gives a higher Aggregate : Binder ratio (by mass and/or volume)

ACID INSOLUBLES AGGREGATE MODE				
SIEVE SIZE	**RETAINED MASS (gms)**	**% RETAINED**	**% PASSING**	**AGGREGATE CHARACTERISTICS**
5.45		12.11	87.88	Angular brown-black iron slag material (coke), some with metallic black lustre (some magnetic magnetite)
2.465		6.52	81.36	As above
0.915		2.48	78.88	As above + very ocassional semi rounded milky/clear quartz grains
0.567		2.79	76.08	As above with greater amount (40 - 50%) of rounded quartz grains
0.411		23.91	52.17	As above with approximately 70% sub angular/rounded quartz grains (most grains are angular)
0.14		13.97	38.19	As above with >70% quartz grains
0.09		12.42	25.7	As above with >80% quartz grains
<0.09		25.77	0	As above

Methodology: A variety of specific volumetric, titrimetric, gravimetric and microchemical techniques, in addition to polarised light microscopy, are used to determine the components and characteristics of the mortar sample, as shown in the results table.

Summary of Results and Comments:

The aggregate: is a fine - medium grained black-brown iron slag material with up to 40% white/milky/clear mostly rounded/sub rounded quartz grains:

Aggregate, mag. x 10

The binder: is an O.P.C. (Portland cement), with extra strength offered by the blast furnace iron slag material, which has a pozzolanic reaction with the free lime in the cement.

The mortar: The black-grey colour of the mortar is a result of the black-grey coloured aggregate.

The Mix Ratio by Volume: is 2.36 : 1 (aggregate : Binder).

Replication Mix: **Parts by Volume**

Iron slag material (fine – medium grained), or PFA
(Fuel ash) mixed with a fine-medium grained sharp sand if
necessary……**2.5** (total)
An NHL 5 (eminently hydraulic lime)
or if necessary a Grey cement Binder (OPC)……..**1**

Head Office:

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HIRST Conservation

London Office:

75 Cowcross Street
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EC1M 6EL
Tel: 0800 068 5418
Website: www.hirst-conservation.com

Mortar Analysis

Date Analysed: 26th July 2016

Sample: 2, South facing external Boiler House wall (phase 5 brickwork), Middleton Top Engine House, Derbyshire.

Observations: A very hard grey coloured dark grey coloured mortar.

RESULTS

Components of Mortar	Method	Results % by mass	
Calcium Carbonate %C	Calcimetry - CO_2 emission	**16.33**	
Dolomite %D	Calcimetry and titrimetric (EDTA)	**0**	
Aggregate	Gravimetric	**71.4**	
Gypsum	Barium Chloride	**0.10**	
Nitrates	Titrimetric/test strips.	**0.039**	
Chlorides	Titrimetric/test strips.	**0**	
Iron Oxides (Fe_2O_3)	Test strips/Titrimetric (potassium dichromate)	**0.4**	
pH of mortar sample	Indicator Strips/pH meter	**9**	
Mix Ratio	**Parts By Mass Aggregate : Binder (A : B)**	**2.5**	
Mix Ratio if binder was lime putty	**Parts By Volume Aggregate : lime putty**	**1.45**	
Mix Ratio if binder was HL/cement	**Parts By Volume Aggregate : Hydraulic Lime or cement**	**1.75**	
Active lime [$Ca(OH)_2$]	Titrimetric (Extracted in 10% sugar solution)	**0.0004**	
Carbonated lime in binder (degree of Carbonation)	From %$Ca(OH)_2$ in binder	**99.99**	
Cementitious Compounds	%S x 2.5	**11.65**	
Soluble Silica %S	Volumetric/Titrimetric - (Conversion to silicomolybdic acid)	**4.66**	
Soluble Silica in Original Binder	From %S x $\left(\frac{A}{B} + 1\right)$	**21.75**	
CaO in Original Binder	From CaO in mortar	**70.88**	
CaO in Mortar	Titrimetric (EDTA) Gravimetric (ammonium oxalate)	**15.19**	
Aluminium Oxide in Binder	Gravimetric (using Oxine)	**-**	
Cementation Index for Binder (CI)	CI ≈ $\frac{\%S \times 2.5}{(\%C \times 0.56) + (\%D \times 1.5)}$	**1.26**	
Type of Binder	Dependent on the % Soluble Silica in Binder	**Cement**	

A lime putty with 50% moisture by mass is considered in the calculations above.A greater percentage of moisture in the lime putty, gives a higher Aggregate : Binder ratio (by mass and/or volume)

ACID INSOLUBLES AGGREGATE MODE				
SIEVE SIZE	**RETAINED MASS (gms)**	**% RETAINED**	**% PASSING**	**AGGREGATE CHARACTERISTICS**
5.45		2.67	97.32	Angular black-grey-brown clinker material (coke-iron oxides, some magnetic)
2.465		15.05	82.27	As above
0.915		15.71	66.55	As above
0.567		13.37	53.17	As above + ocassional clear/white rounded/sub angular quartz grains
0.411		9.03	44.14	As above
0.14		24.74	19.39	As above
0.09		7.69	11.70	As above with >50% white/clear quartz grains
<0.09		11.70	0	As above

Methodology: A variety of specific volumetric, titrimetric, gravimetric and microchemical techniques, in addition to polarised light microscopy, are used to determine the components and characteristics of the mortar sample, as shown in the results table.

Summary of Results and Comments:

The aggregate: is a fine - medium grained black-brown iron slag material similar to that in sample 1, but with negligible off-white ash material and less white/milky/clear mostly rounded/sub rounded quartz grains (20 – 30%).

Aggregate, mag. x 10

The binder: is an O.P.C. (Portland cement), with extra strength offered by the blast furnace iron slag material, which has a pozzolanic reaction with the free lime in the cement.

The mortar: The black-grey colour of the mortar is a result of the black-grey coloured aggregate.

The Mix Ratio by Volume: is 1.75 : 1 (aggregate : Binder).

Replication Mix: **Parts by Volume**

Iron slag material (fine – medium grained), or PFA
(Fuel ash) mixed with a fine-medium grained sharp sand if
necessary……**1.5 - 2** (total)
An NHL 5 (eminently hydraulic lime)
or if necessary a Grey cement Binder (OPC)……..**1**

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Mortar Analysis

Date Analysed: 26th July 2016
Sample: 4, South facing external Boiler House wall (phase 3 brickwork), Middleton Top Engine House, Derbyshire.
Observations: A now powdered, dark grey coloured mortar.

RESULTS

Components of Mortar	Method	Results % by mass	
Calcium Carbonate %C	Calcimetry - CO_2 emission	**14.09**	
Dolomite %D	Calcimetry and titrimetric (EDTA)	**0**	
Aggregate	Gravimetric	**72.72**	
Gypsum	Barium Chloride	**0.093**	
Nitrates	Titrimetric/test strips.	**0.035**	
Chlorides	Titrimetric/test strips.	**0**	
Iron Oxides (Fe_2O_3)	Test strips/Titrimetric (potassium dichromate)	**0.5**	
pH of mortar sample	Indicator Strips/pH meter	**8**	
Mix Ratio	**Parts By Mass Aggregate : Binder (A : B)**	**2.66**	
Mix Ratio if binder was lime putty	**Parts By Volume Aggregate : lime putty**	**1.54**	
Mix Ratio if binder was HL/cement	**Parts By Volume Aggregate : Hydraulic Lime or cement**	**1.86**	
Active lime [$Ca(OH)_2$]	Titrimetric (Extracted in 10% sugar solution)	**3.44**	
Carbonated lime in binder (degree of Carbonation)	From %$Ca(OH)_2$ in binder	**99.99**	
Cementitious Compounds	%S x 2.5	**12.55**	
Soluble Silica %S	Volumetric/Titrimetric - (Conversion to silicomolybdic acid)	**5.02**	
Soluble Silica in Original Binder	From %S x $\frac{(A + 1)}{B}$	**24.50**	
CaO in Original Binder	From CaO in mortar	**69.12**	
CaO in Mortar	Titrimetric (EDTA) Gravimetric (ammonium oxalate)	**14.16**	
Aluminium Oxide in Binder	Gravimetric (using Oxine)	**-**	
Cementation Index for Binder (CI)	CI ≈ $\frac{\%S \times 2.5}{(\%C \times 0.56) + (\%D \times 1.5)}$	**1.58**	
Type of Binder	Dependent on the % Soluble Silica in Binder	**Cement**	

A lime putty with 50% moisture by mass is considered in the calculations above.A greater percentage of moisture in the lime putty, gives a higher Aggregate : Binder ratio (by mass and/or volume)

ACID INSOLUBLES AGGREGATE MODE				
SIEVE SIZE	**RETAINED MASS (gms)**	**% RETAINED**	**% PASSING**	**AGGREGATE CHARACTERISTICS**
5.45		9.96	90.03	Angular brown-black iron slag material (coke, magnetic iron oxides + quartz grains)
2.465		0	90.03	
0.915		5.17	84.86	Angular slag material + 40% off-white/purple-red ash material + angular/sub rounded white/milky quartz grains
0.567		3.58	81.27	As above
0.411		3.98	77.29	As above with >40% white ash material
0.14		33.86	43.42	As above
0.09		19.92	23.50	As above
<0.09		23.5	0	As above

Methodology: A variety of specific volumetric, titrimetric, gravimetric and microchemical techniques, in addition to polarised light microscopy, are used to determine the components and characteristics of the mortar sample, as shown in the results table.

Summary of Results and Comments:

The aggregate: is an iron slag material consising of black-grey coke, black-brown iron oxides (some magnetite with black metallic lustre), sub rounded white/milky clear quartz grains + ,unlike in samples 1 and 2, up to 50% off-white/reddish purple ash material:

Aggregate, mag. x 10

The binder: is an O.P.C. (Portland cement), with extra strength offered by the blast furnace iron slag material, which has a pozzolanic reaction with the free lime in the cement.

The mortar: The black-grey colour of the mortar is a result of the black-grey coloured aggregate.

The Mix Ratio by Volume: is 1.86 : 1 (aggregate : Binder).

Replication Mix: **Parts by Volume**

Iron slag material (fine – medium grained), or PFA
(Fuel ash) mixed with a fine-medium grained sharp sand if necessary……**2** (total)
An NHL 5 (eminently hydraulic lime)
or if necessary a Grey cement Binder (OPC)……..**1**

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Mortar Analysis

Date Analysed: 26th July 2016
Sample: 6, North facing internal Boiler House wall, Middleton Top Engine House, Derbyshire.
Observations: A now powdered, buff coloured mortar.

RESULTS

Components of Mortar	Method	Results % by mass	
Calcium Carbonate %C	Calcimetry - CO_2 emission	**35.62**	
Dolomite %D	Calcimetry and titrimetric (EDTA)	**0**	
Aggregate	Gravimetric	**54.14**	
Gypsum	Barium Chloride	**0.1**	
Nitrates	Titrimetric/test strips.	**0.02**	
Chlorides	Titrimetric/test strips.	**0**	
Iron Oxides (Fe_2O_3)	Test strips/Titrimetric (potassium dichromate)	**0.1**	
pH of mortar sample	Indicator Strips/pH meter	**7**	
Mix Ratio	**Parts By Mass Aggregate : Binder (A : B)**	**1.18**	
Mix Ratio if binder was lime putty	**Parts By Volume Aggregate : lime putty**	**0.68**	
Mix Ratio if binder was HL/cement	**Parts By Volume Aggregate : Hydraulic Lime or cement**	**0.82**	
Active lime [$Ca(OH)_2$]	Titrimetric (Extracted in 10% sugar solution)	**0**	
Carbonated lime in binder (degree of Carbonation)	From %$Ca(OH)_2$ in binder	**100**	
Cementitious Compounds	%S x 2.5	**10.01**	
Soluble Silica %S	Volumetric/Titrimetric - (Conversion to silicomolybdic acid)	**4.0**	
Soluble Silica in Original Binder	From %S x $\frac{(A + 1)}{B}$	**11.61**	
CaO in Original Binder	From CaO in mortar	**68.16**	
CaO in Mortar	Titrimetric (EDTA) Gravimetric (ammonium oxalate)	**23.49**	
Aluminium Oxide in Binder	Gravimetric (using Oxine)	**-**	
Cementation Index for Binder (CI)	CI ≈ $\frac{\%S \times 2.5}{(\%C \times 0.56) + (\%D \times 1.5)}$	**0.50**	
Type of Binder	Dependent on the % Soluble Silica in Binder	**NHL3.5**	

A lime putty with 50% moisture by mass is considered in the calculations above.A greater percentage of moisture in the lime putty, gives a higher Aggregate : Binder ratio (by mass and/or volume)

ACID INSOLUBLES AGGREGATE MODE				
SIEVE SIZE	**RETAINED MASS (gms)**	**% RETAINED**	**% PASSING**	**AGGREGATE CHARACTERISTICS**
5.45		0	100	
2.465		0.38	99.6	Angular brown-black slag material (coke, iron oxides)
0.915		1.53	98.08	As above + >40% off-white ash, white/clear rounded/sub rounded quartz grains
0.567		2.29	95.78	As above + very ocassional red brick dust, but only approximately 30% black-grey iron slag material
0.411		7.66	88.12	Mostly rounded/sub rounded pinkish quartz grains (>90%) + as above
0.14		59.0	29.11	As above with most grains angular
0.09		19.92	9.19	As above
<0.09		9.19	0	As above

Methodology: A variety of specific volumetric, titrimetric, gravimetric and microchemical techniques, in addition to polarised light microscopy, are used to determine the components and characteristics of the mortar sample, as shown in the results table.

Summary of Results and Comments:

The aggregate: consists almost entirely of angular/sub rounded clear/pinkish quartz grains (fine – medium grained) sharp sand + 20% or so off-white ash and very ocassional angular black-brown – grey iron slag material (possibly a contaminant because of very small amount (<2%):

Aggregate mag. x 10

The binder: is equivalent in strength to an NHL3.5 moderately hydraulic lime with possibly some extra strength offered by the small percentage of blast furnace iron slag material, which has a pozzolanic reaction with the free lime in the hydraulic lime.

The mortar: The mortar takes its buff colour from the buff coloured aggregate.

The Mix Ratio by Volume: is 0.8 : 1 (aggregate : Binder).

Replication Mix: **Parts by Volume**

Fine-medium grained sharp sand if……..**1**
Moderately hydraulic lime (NHL3.5)……**1**

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Mortar Analysis

Date Analysed: 30th July 2016
Sample: 7, North facing internal Boiler House wall, Middleton Top Engine House, Derbyshire.
Observations: A now powdered, dark grey coloured mortar.

RESULTS

Components of Mortar	Method	Results % by mass	
Calcium Carbonate %C	Calcimetry - CO_2 emission	**15.66**	
Dolomite %D	Calcimetry and titrimetric (EDTA)	**0**	
Aggregate	Gravimetric	**72.38**	
Gypsum	Barium Chloride	**0.74**	
Nitrates	Titrimetric/test strips.	**0.054**	
Chlorides	Titrimetric/test strips.	**0.55**	
Iron Oxides (Fe_2O_3)	Test strips/Titrimetric (potassium dichromate)	**0.4**	
pH of mortar sample	Indicator Strips/pH meter	**8**	
Mix Ratio	**Parts By Mass Aggregate : Binder (A : B)**	**2.7**	
Mix Ratio if binder was lime putty	**Parts By Volume Aggregate : lime putty**	**1.6**	
Mix Ratio if binder was HL/cement	**Parts By Volume Aggregate : Hydraulic Lime or cement**	**1.9**	
Active lime [$Ca(OH)_2$]	Titrimetric (Extracted in 10% sugar solution)	**0.00005**	
Carbonated lime in binder (degree of Carbonation)	From %$Ca(OH)_2$ in binder	**99.99**	
Cementitious Compounds	%S x 2.5	**10.20**	
Soluble Silica %S	Volumetric/Titrimetric - (Conversion to silicomolybdic acid)	**4.08**	
Soluble Silica in Original Binder	From %S x $(\frac{A}{B} + 1)$	**19.96**	
CaO in Original Binder	From CaO in mortar	**70.88**	
CaO in Mortar	Titrimetric (EDTA) Gravimetric (ammonium oxalate)	**14.48**	
Aluminium Oxide in Binder	Gravimetric (using Oxine)	**-**	
Cementation Index for Binder (CI)	CI ≈ $\frac{\%S \times 2.5}{(\%C \times 0.56) + (\%D \times 1.5)}$	**1.12**	
Type of Binder	Dependent on the % Soluble Silica in Binder	**Cement**	

A lime putty with 50% moisture by mass is considered in the calculations above.A greater percentage of moisture in the lime putty, gives a higher Aggregate : Binder ratio (by mass and/or volume)

ACID INSOLUBLES AGGREGATE MODE				
SIEVE SIZE	**RETAINED MASS (gms)**	**% RETAINED**	**% PASSING**	**AGGREGATE CHARACTERISTICS**
5.45		2.37	97.62	Angular black-brown iron slag material
2.465		3.16	94.466	Angular black-brown sag with black metallic lustred iron oxides (magnetite)
0.915		2.37	92.09	As above + ocassional off-white ash material.
0.567		2.76	89.32	As above + 30% rounded/sub rounded clear/pink quartz grains
0.411		26.08	63.24	As above with > 50% angular/sub angular quartz grains and ocassional off-white ash material
0.14		29.24	33.99	As above, but most grains are angular
0.09		18.97	15.0	As above
<0.09		15.01	0	As above

Methodology: A variety of specific volumetric, titrimetric, gravimetric and microchemical techniques, in addition to polarised light microscopy, are used to determine the components and characteristics of the mortar sample, as shown in the results table.

Summary of Results and Comments:

The aggregate: is a fine - medium grained black-brown iron slag material with up to 40% white/milky/clear mostly rounded/sub rounded quartz grains similar to that in samples 1 and 4:

Aggregate, mag. x 10

The binder: is an O.P.C. (Portland cement), with extra strength offered by the blast furnace iron slag material, which has a pozzolanic reaction with the free lime in the cement.

The mortar: The black-grey colour of the mortar is a result of the black-grey coloured aggregate.

The Mix Ratio by Volume: is 1.9 : 1 (aggregate : Binder).

Replication Mix: **Parts by Volume**

Iron slag material (fine – medium grained), or PFA
(Fuel ash) mixed with a fine-medium grained sharp sand if necessary……**2** (total)
An NHL 5 (eminently hydraulic lime)
or if necessary a Grey cement Binder (OPC)……..**1**

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Mortar Analysis

Date Analysed: 30th July 2016
Sample: 8, South facing external Boiler House wall (phase 4 brickwork), Middleton Top Engine House, Derbyshire.
Observations: A hard, dark grey coloured mortar.

RESULTS

Components of Mortar	Method	Results % by mass	
Calcium Carbonate %C	Calcimetry - CO_2 emission	**14.93**	
Dolomite %D	Calcimetry and titrimetric (EDTA)	**0**	
Aggregate	Gravimetric	**75.73**	
Gypsum	Barium Chloride	**0**	
Nitrates	Titrimetric/test strips.	**0.041**	
Chlorides	Titrimetric/test strips.	**0**	
Iron Oxides (Fe_2O_3)	Test strips/Titrimetric (potassium dichromate)	**0.2**	
pH of mortar sample	Indicator Strips/pH meter	**8**	
Mix Ratio	**Parts By Mass Aggregate : Binder (A : B)**	**3**	
Mix Ratio if binder was lime putty	**Parts By Volume Aggregate : lime putty**	**1.8**	
Mix Ratio if binder was HL/cement	**Parts By Volume Aggregate : Hydraulic Lime or cement**	**2.2**	
Active lime [$Ca(OH)_2$]	Titrimetric (Extracted in 10% sugar solution)	**0.00004**	
Carbonated lime in binder (degree of Carbonation)	From %$Ca(OH)_2$ in binder	**99.99**	
Cementitious Compounds	%S x 2.5	**9.08**	
Soluble Silica %S	Volumetric/Titrimetric - (Conversion to silicomolybdic acid)	**3.63**	
Soluble Silica in Original Binder	From %S x $\left(\frac{A}{B} + 1\right)$	**19.95**	
CaO in Original Binder	From CaO in mortar	**72.33**	
CaO in Mortar	Titrimetric (EDTA) Gravimetric (ammonium oxalate)	**13.18**	
Aluminium Oxide in Binder	Gravimetric (using Oxine)	**-**	
Cementation Index for Binder (CI)	CI ≈ $\frac{\%S \times 2.5}{(\%C \times 0.56) + (\%D \times 1.5)}$	**1.08**	
Type of Binder	Dependent on the % Soluble Silica in Binder	**Cement**	

A lime putty with 50% moisture by mass is considered in the calculations above.A greater percentage of moisture in the lime putty, gives a higher Aggregate : Binder ratio (by mass and/or volume)

ACID INSOLUBLES AGGREGATE MODE				
SIEVE SIZE	**RETAINED MASS (gms)**	**% RETAINED**	**% PASSING**	**AGGREGATE CHARACTERISTICS**
5.45		0	100	
2.465		3.21	96.78	Angular grey-black-brown iron slag material
0.915		13.65	83.13	As above + ocassional off-white ash and rounded/sub angular clear/white/pink quartz grains
0.567		18.47	64.65	As above
0.411		14.45	50.20	As above
0.14		30.52	19.67	As above with more off-white ash and quartz grains. All grains are angular
0.09		7.63	12.04	As above
<0.09		12.04	0	As above

Methodology: A variety of specific volumetric, titrimetric, gravimetric and microchemical techniques, in addition to polarised light microscopy, are used to determine the components and characteristics of the mortar sample, as shown in the results table.

Summary of Results and Comments:

The aggregate: is a fine - medium grained black-brown iron slag material with up to 40% white/milky/clear mostly rounded/sub rounded quartz grains, similar to that in samples 1, 4 and 7:

Aggregate, mag. x 10

The binder: is an O.P.C. (Portland cement), with extra strength offered by the blast furnace iron slag material, which has a pozzolanic reaction with the free lime in the cement.

The mortar: The black-grey colour of the mortar is a result of the black-grey coloured aggregate.

The Mix Ratio by Volume: is 2.2 : 1 (aggregate : Binder).

Replication Mix: **Parts by Volume**

Iron slag material (fine – medium grained), or PFA
(Fuel ash) mixed with a fine-medium grained sharp sand if necessary…….**2** (total)
An NHL 5 (eminently hydraulic lime)
or if necessary a Grey cement Binder (OPC)……..**1**