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The Valley Site
Rhydymwyn, Flintshire

Historic Environment Management Plan

Volume 1

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The Valley Site, Rhydymwyn, Flintshire: Historic Environment Management Plan

Volume 1

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The Valley Site, Rhydymwyn, Flintshire:
Historic Environment Management Plan

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SUMMARY

The site occupies around 35 hectares of the Alyn Valley, to the south of the village of Rhydymwyn, Mold, Flintshire, (centred on SJ 205 668). Once part of the extensive Gwysaney Estate, the Parish of Rhydymwyn was established in 1865. Lead mining in the area is known to have been extensive, and a foundry associated with nearby mines is depicted on several early maps for the area. Following the closure of the foundry land use on the site was largely agricultural in character. However, in 1939 the land was purchased by the Ministry for Supply and developed as a purpose built chemical weapons factory and storage facility.

Over 100 specialised buildings were constructed across the site, linked by an extensive rail network established around a spur off the Chester to Denbigh mainline. Other major landscaping undertaken at this time included the canalisation and culverting of the River Alyn, and the excavation of a complex of interlinked subterranean, rock-cut tunnels and caverns. During World War II the plant produced ordnance containing mustard gas, and was associated with the development of the Atom Bomb. In the immediate Post-War period the site was used to store German nerve gas, and it was not until the 1960s when Britain relinquished its chemical weapons (CW) capability that the site as a chemical storage facility was defunct. However, the site remains on the international Chemical Weapons List, and is still monitored as such.

From the mid-1960s the site was used by various governmental departments, its major function being a buffer storage depot to supply emergency rations and foodstuffs, and associated facilities such as mobile bakeries and canteens. In 1994 the site was finally closed, and a programme of demolition was undertaken. This involved the dropping of buildings onto their footprints, and the rubble being mounded over with topsoil. However, several major structures, and many ancillary buildings, still survive across the site.

In recent years a not insubstantial amount of work has been undertaken on the site; this has included condition surveys of the surviving building stock, geophysical survey, and some exploratory groundworks. However, none of these pieces of work has been undertaken within an archaeological or historical framework. For this reason a Historic Environment Management Plan was commissioned by DEFRA, the results of which are reported upon here.

The surviving buildings are a good reminder of a huge building programme that changed the face of Britain forever. But, as with many other purpose-built structures once their original function is removed they are notoriously difficult to convert and reuse. In this instance the problem of function is further compounded by the site's association with chemical warfare; which is undoubtedly a highly emotive subject. For this reason it has been a priority of this project to assess the significance of the surviving buildings in terms of their group value and national and international significance.

The site is as unique today as it was at its inception, and this raises several issues with regard to its future management. Although there is no risk to public health, access to the site must, of necessity, remain restricted. However, new ecological initiatives have proved highly successful, and it is hoped that the historical significance of the complex can be used in tandem with the ecological management plan to raise the profile of the site and increase its value as an educational resource.

MS VALLEY SITE, RHYDYMWYN, FLINTSHIRE:
HISTORIC ENVIRONMENT MANAGEMENT PLAN

INTRODUCTION

Birmingham Archaeology was commissioned by the Department for Environment Food and Rural Affairs (DEFRA), to undertake a programme of archaeological research and recording, and prepare a Historic Environment Management Plan on and for the former MS Valley Site, Rhydymwyn, Flintshire, North Wales (hereinafter referred to as the site). This work was administered by Carillion and monitored by the Clywd-Powys Archaeological Trust (CPAT).

This report outlines the results of archive assessment, documentary and cartographic research, field evaluation and building recording which were carried out between January and March 2006. This report has been prepared in accordance with a Scope of Works prepared for the client by Clywd and Powys Archaeological Trust (CPAT), and a Written Scheme of Investigation (Nichol and Litherland 2005) which was approved prior to implementation.

The Assessment and Management Plan included:

- Assessment of the on site documentary archive held at the Valley Site Visitor Centre.
- Collation of background historical information through desk top survey and map regression analysis.
- Assessment if the current survey record of the underground chambers, with proposals for further detailed archaeological survey/recording as appropriate.
- Archaeological recording of surviving buildings and structures, including condition survey.
- Making a digital video record of the site.
- Analysis and assessment of the historic significance of the site and its surviving buildings and ancillary historic features, including condition survey.
- Preparation of proposals for public interpretation/engagement.

FORMAT OF THE REPORT

Due to the volume of information generated by the assessment the results of the research, survey, and management plan have been compiled in 3 separate volumes (each with its own appendices but a single combined bibliography located at the end of Volume III).

Volume I covers points 1 and 2 of the above task list and includes a gazetteer of pre-factory industrial features surviving across the site. It also discusses the background to the building of MS Valley Site and gives an introduction to the chemical processes that were undertaken there.

Volume II covers points 3 and 4 of the above task list and includes detailed survey plans, elevations and photographs of every building on the site and ancillary features of a wartime date.

Volume III covers points 6 and 7 of the above task list and includes point 5 as a cd appendix.

CHAPTER 1 ASSESSMENT OF THE DOCUMENTARY ARCHIVE

Kirsty Nichol and Professor Timothy Peters
With contributions by Jill Gillespie and Julian Cruickshank

1.1 Introduction

A total of 12 boxes of documents relating to past usage and layout of the site was held at the time of the assessment on site at the Visitor Centre. Work included:

- Compilation of an inventory of contents.
- Basic archiving into appropriate categories, and re-boxing, to aid its usage for other elements of the assessment, for example building recording.
- Compilation of a list of relevant documents held by other repositories.
- Summary statement of significance of the archive to include:
- Recommendations for future storage.
- Recommendations for the dissemination of the information held therein.

1.2 Methodology

In order to aid this exercise, and future identification of items within the collection, a new (temporary) number was given to each individual box (Rhyd1 etc, Table 1). Details of articles contained in each box were then entered directly onto an excel spreadsheet (see Appendix I). Where numbers had already been allocated from earlier archiving exercises these were also recorded to aid future cross-referencing of indices. Over 300 articles were catalogued during the course of the assessment.

Where an ITEM number is recorded it is possible to cross-reference with the archive established by AEA.
Where the article begins with a V/ these are the original war-time (early post-war) codes used to reference the documents.
All documents beginning with GWF are relatively recent acquisitions and may be subject to the thirty year rule.
Some documents had no defining number but have been described or their title recorded.

A wide variety of documents make up the paper archive for the site, these include both copied and original texts (although this was not noted during the phase of assessment):

- Memoranda
- General Correspondence
- Minutes of Meetings
- Inventories
- Finance Details
- Specialist Reports
- Maps and Plans
- Photographs

They date from 1939 onwards, and can be divided into key phases of the site's occupation.

1939-1945	Establishment and running of the facility
1946-1950s	Decommissioning of the facility
1980s	Reuse of the site as a buffer depot

1990s Large scale remediation works being undertaken across the site, and public engagement

Throughout all periods there has been almost constant monitoring of toxic levels and exercises of decontamination which are well documented.

Box	Description	Date
Rhyd1	Reports and Minutes.	Mainly 1940s (some 1960s)
Rhyd2	Minutes	1945-1957
Rhyd3	Contaminated Land Investigation	1985-1987
Rhyd4	Misc	1944-1985
Rhyd5	Correspondence and Reports	1960-1996
Rhyd6	Technical Reports, minutes	1939-1945
Rhyd7	Reports, minutes and memos	Mainly 1940s
Rhyd8	Reports, photographs and plans	Mainly 1980s
Rhyd9	Plans	1940-1942
Rhyd10	Remediation Works and Conversion	1997-2004
Rhyd11	Correspondence, reports and plans	1987-2005
Rhyd12	Correspondence	1996-2002
Rhyd13	Correspondence and Finance	1994-2003
Rhyd14	Generic Code for Loose Maps (tubes)	
Rhyd15	Assorted loose reports	1985-2001

Table 1 Rhydymwyn Archive Contents List (Box Description)

Also included in Appendix I are lists of items relating to the site that are held at other repositories, these have been coded as follows:

FRO Flintshire Record Office, Hawarden, North Wales
TNA National Archives, Kew, London

It should also be noted that Denbighshire Record Office hold duplicates of what is located at Flint Record Office (FRO), with no additional information. Also, neither Wrexham nor Conwy Record Offices hold any archives relevant to the site.

1.3 Statement of Significance

Documents in the collection represent a good cross-section of the type of documentation associated with a facility such as this, however there are obvious gaps in what has survived, at least with regard to the archive currently held on site. There is little or no personal detail in any of the documentation, and although there is a list of drawings known to have been associated with the site these no longer appear to be part of this collection.

These documents are an important record for what is one of the last survivors of one of North Wales' best kept secrets. Although the archive is incomplete, enough documentation survives for researchers to understand the systems flow around the facility, and the huge emphasis that was put upon the safety of the site personnel and the smooth running of the plant. It also allows an insight into the problems of maintaining such a facility once its original function has been removed.

1.4 Recommendations

Further Assessment

All the government records held on site at Rhydymwyn are public records, and as such are subject to the statutory terms and conditions of the Public Records Act 1958.

Under Section 3 of the Act-

"It shall be the duty of every person responsible for public records of any description which are not in the Public Record Office or a place of deposit appointed by the Lord Chancellor under this Act to make arrangements for the selection of those records which ought to be permanently preserved and for their safe-keeping."

It is therefore the responsibility of the originating government departments and the National Archives to review and make the decision on what records are to be preserved, where the selected records should be kept, and what should happen to any records not selected for permanent preservation.

In consultation with Jill Gillespie from the National Archives, it is therefore recommended that at the end of the current project the records will either be removed from the Visitor Centre and be taken back to the government department responsible for a full appraisal of the record to take place, or this would be done on site.

Future Deposition

Following further assessment a decision will be made regarding where the records should be stored, and personnel from the National Archives will discuss the selection decisions with Flintshire Record Office and the Ancient and Historic Monuments of Wales, and DEFRA.

Visitor Centre Educational Archive

The National Archives would also be happy to assist in providing copies of any documents for the Rhydymwyn Visitor Centre once the selection process had been completed, and the relevant government departmental permission obtained (Jill Gillespie pers. comm.). Some of the documents dating to the war time period have degraded and become fragile, and it is therefore recommended that these be scanned for conservation purposes. This will also aid dissemination of the archive in the future, by allowing documents to be made into acrobat files and made available through either the site's own website, or through that of the repository for the whole, or any part of the archive.

The later material relating specifically to the management of the site is considered not to be of educational value. As such, it is recommended that it is retained as a part of the site archive, but that it is not made available to the general public on site.

It is felt that certain archival resources should be held on site as part of the planned growth of the on-site educational facility. These should include (as a minimum):

- Copies of documents relating to the foundry and mine working (currently held at Flint Record Office)
- Copies of early maps (Currently held at Flint Record Office)
- Copies of war time documents relating to the running of the factory (to be made available by TNA)
- Copy of the Maud Report (in light of recent findings relating to the Tube Alloys Project)
- Photographic Archive to include the collection at Flint Record Office that will shortly be available in digital format.

These sources should be integrated with the site GIS, and could potentially be made available through links on the website. It is envisaged that they would also provide a useful resource for any future projects undertaken by the Friends of the Valley, and form the basis of historically based education packages.

CHAPTER 2 HISTORICAL OVERVIEW

Nigel Pearson and Kirsty Nichol

2.1 Introduction and Methodology

Historical research was undertaken ahead of, and in tandem with, the survey of the standing buildings in order to set the buildings in context and to facilitate their interpretation. The range of sources accessed included primary, secondary, cartographic and pictorial records held at the regional HER, Flintshire Record Office, and national collections held by the National Archives, Kew, and the Imperial War Museum, and DEFRA's own on site GIS (as outlined in the 'Standard and Guidance for Desk-Based Assessments' (IFA 1999)).

Historical analysis has also been used to identify the potential for below-ground archaeological survival of pre-factory features within the early industrial landscape in order to inform the future management of the site.

This type of interdisciplinary approach has taken into cognisance recent developments in conservation-based research and analysis. The present study has sought to develop the findings of earlier surveys and unpublished research with the overarching aim of dating the surviving buildings and understanding the significance of the change to the village brought about by the establishment of the factory within the broader social history of the development of the area and the effect that the war had on the local population. This is also the point of linkage with local, regional and national research issues concerning the impact of World War II both socially and industrially.

Alongside the building recording, and documentary research a walkover survey was undertaken in order to identify other features of the complex not covered by building recording. A block of primary record numbers was obtained from the SMR prior to work commencing on site, and all new features identified as part of the survey received its own unique identifying number (Appendix II). Recording of these features involved:

- A brief written record
- A photographic record
- Plotting of location on GIS
- Record of their condition
- Compilation of a gazetteer

2.2 History of the Study Area

The village of Rhydymwyn is located two and a half miles northwest of Mold, in the county of Flintshire. The site of the former MS Valley Site, (now known as number 17 Nant Alyn Road) occupies around 35 hectares of the Alyn Valley, immediately to the south of the village (centred on SJ 205 668). The Alyn is a small river that rises in the Clwydian mountain range, and drains into the River Dee near Mold. Here its valley is fairly steep, and the underlying geology is limestone. Today the site lies to the south of the main residential part of the village. The eastern boundary is defined by the former line of the Mold and Denbigh Junction Railway (LNWR/LMS), with the Antelope Industrial Estate immediately to the east. The western boundary cuts through agricultural land.

The village itself lies within the former parish of Gwernaffield which was established in 1865 out of portions of townships in the parishes of Mold, Cilcain, Northop and Halkyn (Genuki). Rhyd-y-meryn originally lay in the Hundred of Mold, which is described in Slater's Directory of 1868 as being:

"…agreably situated on the River Alun or Alyn, in the midst of a pleasing and fertile country, and in a district rich in coal and lead. It is a place of considerable antiquity supposed to have been a station of the Romans, but the derivation of its name is not on record."
(Slater 1868, vip 87).

The Historic Environment Record compiled by CPAT indicates that the majority of recorded archaeological features in the vicinity of the study area provide evidence of post-medieval lead and lime mining. Although evidence of earlier activity exists within the broader area in the form of several tumuli, the Celtic hillfort of Moel y Gaer, Wat's Dyke, the 5th century battlefield site of Maes y Gamon, and the 17th century houses and gardens of Rhual Hall and Gwysaney Hall. The study area is located within the Northeast Wales Orefield which is rich in lead and minor zinc ores that have been mined since the Bronze Age. However, it was not until the Industrial Revolution that mining began to have a major impact upon the environment and landscape of the region (Jones et al 2004, 2). Ores are found locally in narrow veins (or lodes) and in joints (or flats) in the local limestone, with the most productive being found within the Cefn Mawr Limestones. The Bryn Celyn Vein is the most important vein so far as the study area is concerned, as it runs under the former bed of the River Alyn from Nant to the site of the early foundry (Smith 1921, 80), this appears to be the only instance in the vicinity of ore being followed up the sequence as high as the Holywell Shales (Cruickshank 1996b, 4).

Historically, mining in the region has experienced serious problems with water, and many early mines had a history of closure or intermittent work due to flooding, with mining being an almost seasonal activity. In 1818 the Halkyn Drainage Level (or Halkyn Deep Level Tunnel) was begun a few kilometers to the northeast of Rhydymwyn. It was cut across the strike of the veins, allowing drainage from overlying strata and mines. In 1896 a second drainage tunnel, the Milwr, or Sea Level, Tunnel was begun by the Holywell-Halkyn Mining and Tunnel Company. These tunnels originally drained the Halkyn Mountain and Holywell Mines, but eventually reached the Mold Mines too. The Halkyn Tunnel lies between 79 to 80m Above Ordnance Datum (AOD) where it crosses under the study area, and the Milwr Tunnel lies around 22m AOD as it skirts the western boundary of the site. These drainage tunnels had the combined effect of lowering the water table so successfully that the Halkyn Level more or less dried up. However, some efforts were made to maintain a flow as the discharge from the Halkyn Level contributed to the water supply of a World War I munitions factory at Queensferry, 14km to the east of the site (Cruickshank 1996b, 5).

The limestone substrata, particularly the lower series (Cefn Mawr and Loggerheads Formations), contain numerous cave and pothole systems that transmit large volumes of water. One of the main systems is known as Ogof Hesp Alyn, and is known to be connected to swallow-holes on the bed of the River Alyn. When the Halkyn Drainage Level revealed the South Llyn-y-Pandy lode in 1901 it captured water from this system and afterwards the River Alyn ran dry as far as Rhydymwyn. The local water table was further lowered when the Milwr Tunnel here in 1936. Subsequent attempts by the Halkyn District United Mines Limited (HDUM) to seal off swallow holes on the riverbed were largely unsuccessful and the river flow has never been fully restored (ibid).

Several other veins have been identified a little to the west of the study area, called (from north to south) Pen-y-Fron and Bryn Celyn, Llyn-y-Pandy, South Llyn-y-Pandy and Pant-y-Mwyn. Two of these - the Llyn-y-Pandy veins - have not been traced as payable lodes as far east as the study area, but appear to terminate in the vicinity of the Bryn Celyn Cross Course. The Pant-y-Mwyn Vein has been traced to the site boundary. It was accessed from the Bellan Level, or adit, driven from within the works; however, there are no recorded underground workings on this vein beneath the site (Cruickshank 1996b, 6).

2.3 Cartographic and Documentary Research

The earliest cartographic evidence for the study area is from the Gwysaney Estate Map of the Davis/Cooke family of circa 1757. This shows that most of the land now occupied by the site, and its immediate vicinity, was owned by A. L. Swymmers Esq. and the Williams Family (Plates below). Rhyd ŷ mwyn Lead Works is annotated twice, and a single mine shaft (with a horse whim or gin) and waste tip are depicted here, whilst five more waste tips and a second whim are shown slightly further to the west (see detail below). The part of the Lead Works located within the study area was fed by a leat from the River Alyn (SMR 98071) that powered two water mills, which are depicted diagramatically. The leat discharged into the River Alyn downstream of its confluence with the Dolfechlas (or Mechles) Brook to the south. Several other buildings are depicted clustered around the mine workings, and were presumably workshops and stores.

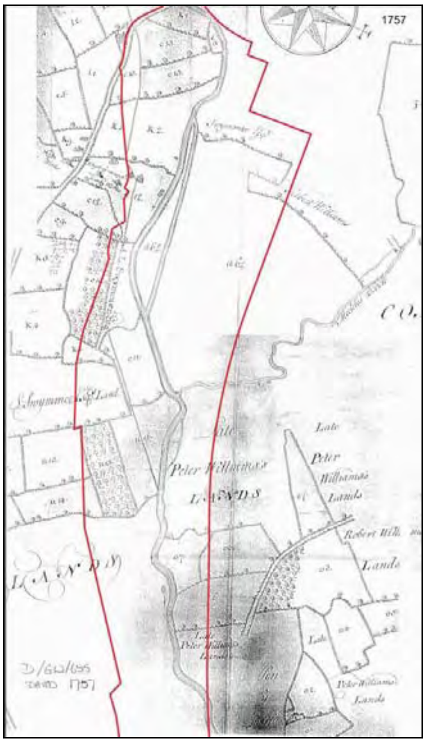


Plate 1a 1757 Plan with outline of the site in red

Plates 1b (above) and 1c (right) depicting 1757 Plan

During this period water-power was more commonly used to drive pumps or processing machinery (such as water-powered stamp mills) than steam powered engines (Walters in Jones et al 2004, 20). Stamp mills first appeared in the 1780s, and hammers used to pound the ore were often driven by waterwheel (Walters in Jones et al 2004, 18). It is therefore possible that the water mills depicted on the 1757 Map are evidence of relatively early mechanised processing of ore. Alternatively, one, or both, waterwheels could have been associated with corn milling. To the east of the Lead Works a section of the River Alyn appears to have been diverted to form a mill race. This may represent even earlier (pre-1757) industrial activity here.

In a lease dated 30th December 1827 John Taylor, a local mining engineer, assumed responsibility for 'all mines of lead, copper, booze, sythom, calk and calamine under Alyn Bank and belonging to P. B. Davies Cooke Esq. for a period of 40 years at a rent of £1 per ton of lead, 10s per ton of black jack, calk or calamine and 1/10 part value copper' (FRO D/GW/588). Taylor was, at this time, the mineral agent for the Grosvenor family, the largest mine owners in the area in the 17th and 18th centuries, and during this period investment in what became known as the Mold Mines was significant (Williams 1979-80, 21).

Plate 2 Geological/Mine section showing shafts and adits

The underlying alluvial gravels in the eastern part of the site meant that the early workings (as depicted on the 1757 Map) were very liable to flood. However, in 1827 the Brick or West Iron Shaft (CPAT HER 18195) was sunk – probably by John Taylor - as a pumping engine shaft. It was brick walled, with an inner water-tight iron lining (ibid, 23), and employed a 46" cylinder steam pumping engine. Steam engines were more commonly used in Flintshire and Denbighshire than elsewhere in Wales, as there was a more ready supply of coal locally (Walters in Jones et al 2004, 20). A representation of the Pen-y-fron and Rhyd-y-mwyn

Geological/Mine Section (above) is dated to the late 19th century, but is perhaps more likely to be circa 1827. It shows (from west to east) Rundee Shaft, Wheel Shaft, Whim Shaft, Payn's Shaft and Brick Shaft, with a maze of inter-connected adits, cutting through the shelving sub-strata. The section also depicts a steam engine above Brick Shaft, the shaft head of which is still visible on the ground today within the bounds of the site (Plate 3 below).

Plate 3 Brick Shaft (CPAT HER 18195)

At Wheel Shaft, originally located at the southern end of the foundry site, an overshot waterwheel is shown. Documentary evidence reveals that this was a 44ft waterwheel, with an 8ft breast, that drove 18" pumps (Williams 1979-80, 29). Whim Shaft is in fairly close proximity to the waterwheel, and an aerial link between Brick and Whim Shaft is also depicted. This probably used flat rods to work pumps in Whim Shaft. These rods were a common means of transferring motion at the time, and moved backwards and forwards, supported on hinged pivots (pers. comm. C.J. Williams). Rundee Shaft is also shown further up the hillside to the west of the site.

The Tithe Map of Gwernaffield (Mold) Parish (Figure 1 below), surveyed between 1837-39, reveals that land within the site was less enclosed than it had been eighty years earlier, there are also fewer references to woodland. No mine workings are depicted, and only the northern part of the leat that featured on the earlier Estate Map is shown here, appearing to flow into a round pool. Where the river channel had been canalised to form a mill race on the early map, the original course of the river is no longer evident on this later map. Presumably it had either silted up, or run dry, and the river bed reclaimed.

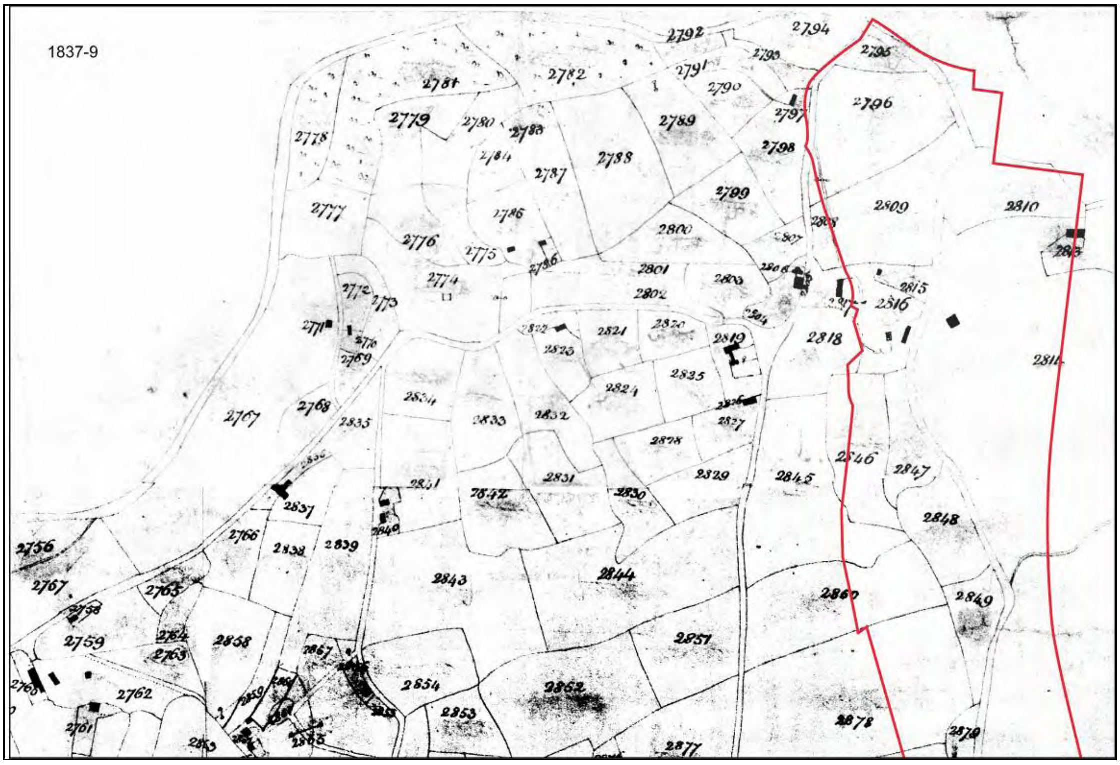


Figure 1 Tithe Map (1837-9)

The Apportionment for the Tithe Map (above) shows that the principle landowner in the district was Philip Davies Cooke Esquire, and it was to him that the chancel in St John's Church was eventually raised in memoria (Slater 1895, 324). Records show that whilst he retained ownership of the Rhydymwyn Works (the foundry) he also rented land and houses to tenant farmers such as George Adams, John Frances, Robert Mathews, and John Williams. Although no mines are shown there are clues in the field name evidence. Pwll, for example (see table below), translates as pit, pool, pond or mine. Cooke was also recorded as retaining an area where mine waste had been dumped to the west of the site (Field Numbers 2776-7; Figure 1 above).

Plan No.	Description	Occupier
2795	Ddol bach (paddock)	Robert Mathews
2796	Dol boyn y buarth	George Adams
2808	Part of Dol Dafydd prid	Robert Mathews
2809	Ddol Dafyddprid	Robert Mathews
2810	Ddol beltaf	Robert Mathews
2813	House and Gardens	John Williams
2814	Dol Fawr	John Williams
2815	House, Garden & ???	John Williams
2816	Rhydymwyn Works	Philip Davies Cooke
2817	House and Garden	John Francis
2818	Cae taw twmpath	George Adams
2845	Cae Pwll (Mine Close?)	Robert Mathews
2846	Cae Ffynon	George Adams
2847	Meadow	
2848	Gulfach	George Adams
2849	Meadow	Robert Mathews
2850	No details	
2878	No entry	
2879	Little Meadon	Edward Davies

Table 2 Field details taken from the Tithe Apportionment

Following his earlier lease of the mineral and mining rights, Taylor was recorded (in 1839) as leasing the Rhydymwyn Foundry (SMR 98070) from Cooke for a period of 40 years (FRO D/GW/594), in order to provide products, such as beam engines, to mines in the area. However, as the Tithe Map reveals, local mines were in heavy decline by this period (the Rhydymwyn Mine having closed around 1837 (Williams 1979-80, 23)), so the works turned to making mining machinery for export (ibid, 24). Nonetheless, John Taylor and Co., Rhyd y mwyn, are recorded under Iron and Brass Founders in Slater's Directory of 1844, and John Taylor is reported to have made a 50" cylinder, 10ft stoke, pumping engine for the Talargoch mine in July 1845 (Thorburn 1986).

A plan of land 'in the Parish of Mold belonging to P.D.Cooke Esq ' drawn up in 1850 (Figure 2 below) focused upon a field to the east of the river, which was previously recorded as Dol Fawr (meaning much or large field) on the Tythe Map. This plan shows an embankment along the southeastern boundary of this field, together with sections bordering the River Alyn. This may have been constructed in order to alleviate flooding, as can be seen today along stretches of the river towards Mold. However, it is equally possible that the earthworks were designed to maintain the field as a water meadow, although one would expect more evidence of leats, feeders and sluices to be associated with such a scheme. The eastern edge of the foundry is also depicted on the plan, as well as a trackway cutting through the field and a bridge over the river giving access to the foundry. Immediately north of this bridge a weir, (that probably impounded the wider stretch of river upstream to power a waterwheel within the foundry) is located in the approximate position of the northern tip of the 'island' depicted on the earlier 1757 Estate Plan.

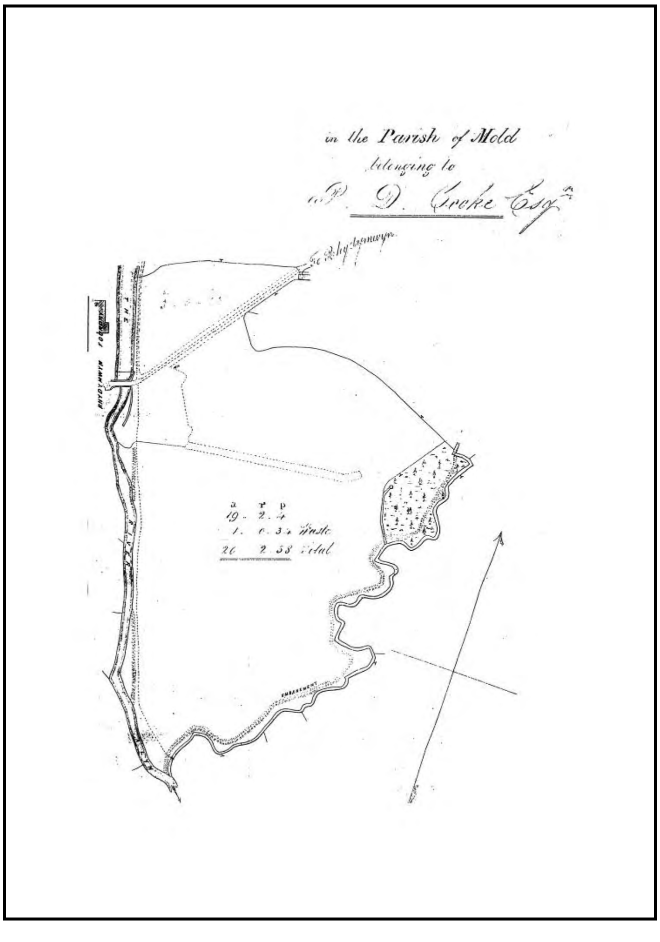


Figure 2 Plan of land in the Parish of Mold belonging to P.D.Cooke dated 1850

The layout of the foundry can be seen in much more detail on a second plan of land belonging to Cooke, dated to 1859 (Figure 3 below). It reveals that the foundry had a large square header pool to the north of the complex, which was fed by the impounded stretch of the River Alyn. Immediately to the south of this pool the river split at the weir, with a leat running off and defining the eastern limit of the foundry complex proper. It is possible that water from the header pool also drained southwards (in an underground culvert) along the western side of the complex. This may then have joined with water from the sluice gates at the weir to drive a water wheel housed at this junction. Water would then have flowed back into the river further downstream.

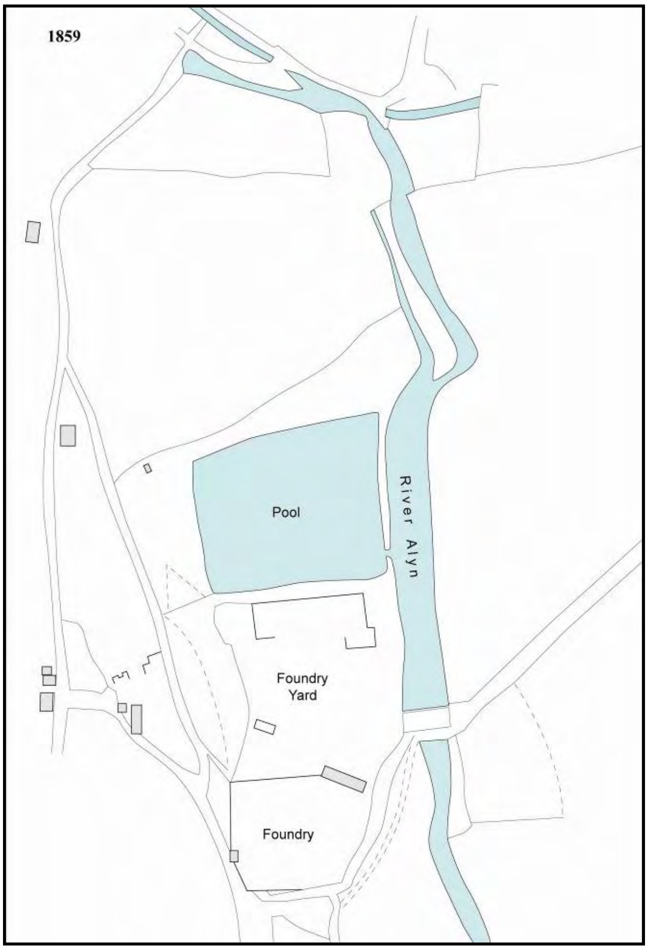


Figure 3 Plan of land belonging to P.D. Davies Cooke dated 1859

The Foundry Yard was immediately adjacent to the weir, with the principle foundry buildings to the south. A section of wall (SMR 98049) still survives on the ground today and probably relates to the structure depicted on the western side of the Yard, as there is evidence for the southern wall surviving as a scar (see Appendix II). The revetment wall (SMR 98051), cut into the hillside, continues northwards, along the western extent of the foundry complex, and this is also visible on the ground today (Appendix II). Several routeways into the foundry are shown, the path of the northernmost track on the plan is visible as a field boundary on later maps, and followed today on the ground by the boundary fence of the site. The trackway to the south (SMR 98050, see Appendix II) was reused during World War II as a possible emergency escape route from the factory, it survives well on the ground today. However, the main entrance to the complex by 1859 was most probably the track cut through fields on the valley floor to the east, which linked up with the main turnpike road.

In 1863 Taylor moved his foundry to a more favourable location at Sandycroft, 18 km to the east, on the River Dee. Here it continued to manufacture ore-dressing plant, winding engines, waterwheels, pumps and other products (including electric motors) until it closed in 1925 (Williams 1979-80, 24). Taylor gave notice in a letter to P.D. Davies Cooke of his intention to quit on the 29th September 1863, thereby giving him one year's notice (FRO D/GW/594). There are also records showing that upon leaving the foundry site, Taylor left behind equipment worth £350, which included a 20ft waterwheel as well as forging equipment (FRO D/GW/B/594).

Subsequent to Taylor's departure, an entry in Worrall's Directory for 1874 describes the site of the foundry as being in a derelict state. He writes:

> 'Rhydymwyn is a village in the parish of Cilcen, four miles from Mold, and a station on the Chester, Mold and Denbigh Line. The ecclesiastical population is 526. Here is a church and school, and also two places of worship for dissenters, viz.: Baptists and Welsh Wesleyans. Formerly there was an extensive ironworks here, but having been closed for some years the buildings are now in ruins.
>
> The village is surrounded by lead and coal mines, and the River Alyn not only adds to the beauties of the scenery, but is highly beneficial in turning the ponderous wheels connected with the lead mines and flour mills.'

(Worrall 1874, 53-54)

The remains of Rhyd-y-mwyn Foundry were shown on the First Edition Ordnance Survey Map of 1878 (1:2500 County Series, Figure 4 below), although the previous years of neglect were much in evidence. The header pool although still discernable, had silted up to form a marsh. The weir and sluice both survived, as did the leat curving around the southern extent of the site. The tailrace was shown in roughly the same position as the leat indicated on the 1757 Estate Plan. The fact that this leat was not shown on the Tithe Map may simply be because it was not been surveyed, as such a feature was not taxable. It is possible that a wall (SMR 98072), (a fragment of which survives in the study area, but which is largely outside the fence line) represents a formalisation of the field boundary which it appears to follow up the hillside, and which was probably originally the northern extent of the foundry complex.

The revival in the district's mining industry is also very much in evidence. The lead shaft immediately to the south of the foundry buildings, was probably Whim Shaft, and beyond the western boundary of the study area lay waste tips and 'Old Shafts (Lead)' marking the location of Davey's shafts on the hillside above the valley. There were also limekilns, quarries and other lead mining shafts depicted in the surrounding area. One shaft of particular interest, the Erw Felin shaft and adit, situated on the hillside to the north of the study area was reused during the Second World War as a source of water for cooling and process purposes at the Valley Factory, but in an emergency it could also be used for fire fighting and the boilers (see Bone below).

The village of Rhydymwyn itself consisted of only a few houses in the later Victorian period, along with St John's Church and Vicarage, a Flour Mill (SMR 98061), complete with mill race, and the Antelope and Gwysaney Arms Public House. Worrall's Directory of 1874 records Rev. James Jones as the vicar, John Lloyd as the publican, brewer, and car and coach proprieter at the Antelope, and Robert Davies as the Miller at this time (Worrall 1874, 54-61). The mill race for the Flour Mill is still visible today as an earthwork in woodland to the northwest of the site. A cluster of features, that includes masonry associated with the weir and mill leat (SMR 98060), a bridging point over the Alyn, stone-lined leat (SMR 98058) and wheel pit (SMR 98057) also survive on the ground. These represent a good cross-section of the type of features associated with industry and water management in the area during this period. What is also interesting from the map evidence is that there does not appear to be much workers housing in the village, perhaps suggesting that employees may have come from Mold. The Wesleyan Methodist Chapel and cluster of miners cottages to the south of the study area, at Llyn y pandy, is, however, a good example of the type of settlement at this time in this region.

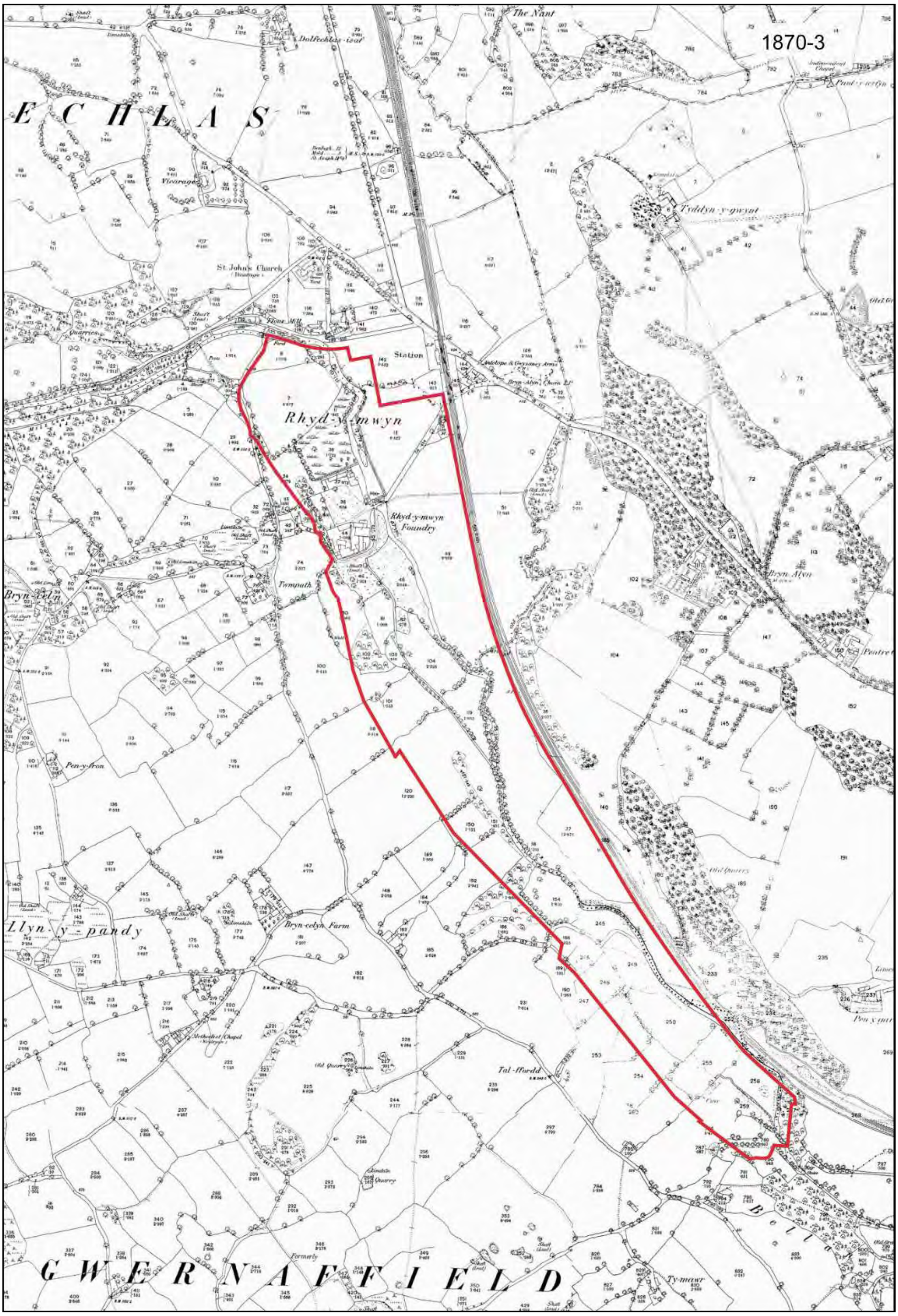


Figure 4 First Edition Ordnance Survey Map

Alongside the industrial revival of the area improvements were made to the transport infrastructure around the village. The old Wrexham-Denbigh Road (the modern A451) was turnpiked back in 1758, and the Mold and Denbigh Junction Railway cut in the mid 1800s, with the station at Rhydymwyn in 1869 (Wright 2006). The track cut through the large field on the eastern side of the river, and today forms the eastern boundary of the study area. Worrall's Directory of 1874 records David Parry as the Station Master at this time (Worrall 1874, 57).

Much of the 19th century expansion in mineral mining saw known sites being revisited and reworked as extensions of the main lodes were followed and mines became deeper (Walters in Jones et al 2004, 18). Adits were used to access levels and drain the workings that enabled mining to take place year round and allowed for much deeper shafts. Although there are records to show that lead mining had ceased at Rhydymwyn by 1837 (Clwyd County Council 1978), mining was resumed, around 1890, under the South Halkyn and Rhydymwyn Mining Company (Burt 1992, 43). Records show that at it's height, in 1899, the company's workforce totalled 103 men (with 50 of them being underground workers), but by 1902 only one surface worker was listed (ibid). Matthew Francis was the local agent for the mining company during this period, residing at the Old Hall, Halkyn (Slater 1895, 330).

By the late 19th century Flintshire was second only to the Pennines in terms of lead ore production (Walters in Jones et al 2004, 24). Evidence for this intensive, period of mining is reflected by the number of spoil heaps depicted on the Second Edition Ordnance Survey Map surveyed in 1900 (Figure 5 below). By this time the old foundry buildings were used by a Saw Mill, probably providing pit props for the surrounding mines, although several of the smaller ancillary mine buildings had been demolished. Development of the railway network further aided the expansion of the mines, and a siding off the Mold and Denbigh Junction main line helped to ship ore from the processing area in the valley.

Several new shafts were sunk during this period of renewed activity, as well as older shafts being re-opened. Brick (West) Iron, Rundee, Davy's/Dyer's and Wheel/Whim are listed as 'Old Shaft(s)'. However, Brick (West) Iron was marked as having a waste tip, and there was head gear in evidence. There are also many more waste tips depicted in the study area which suggests that a lot of processing had been undertaken on the site in the ensuing period. Waste tips are also visible in what was originally the foundry yard, and it is possible that this part of the complex may have been used for jigging the crushed ore. Also, marked for the first time, was an old shaft, adjacent to the confluence of the tailrace and the River Alyn to the south of the main complex.

In the southern part of the site another trackway is visible entering the valley from the west. This survives on the ground as a hollow way (HER 98052, Appendix II).

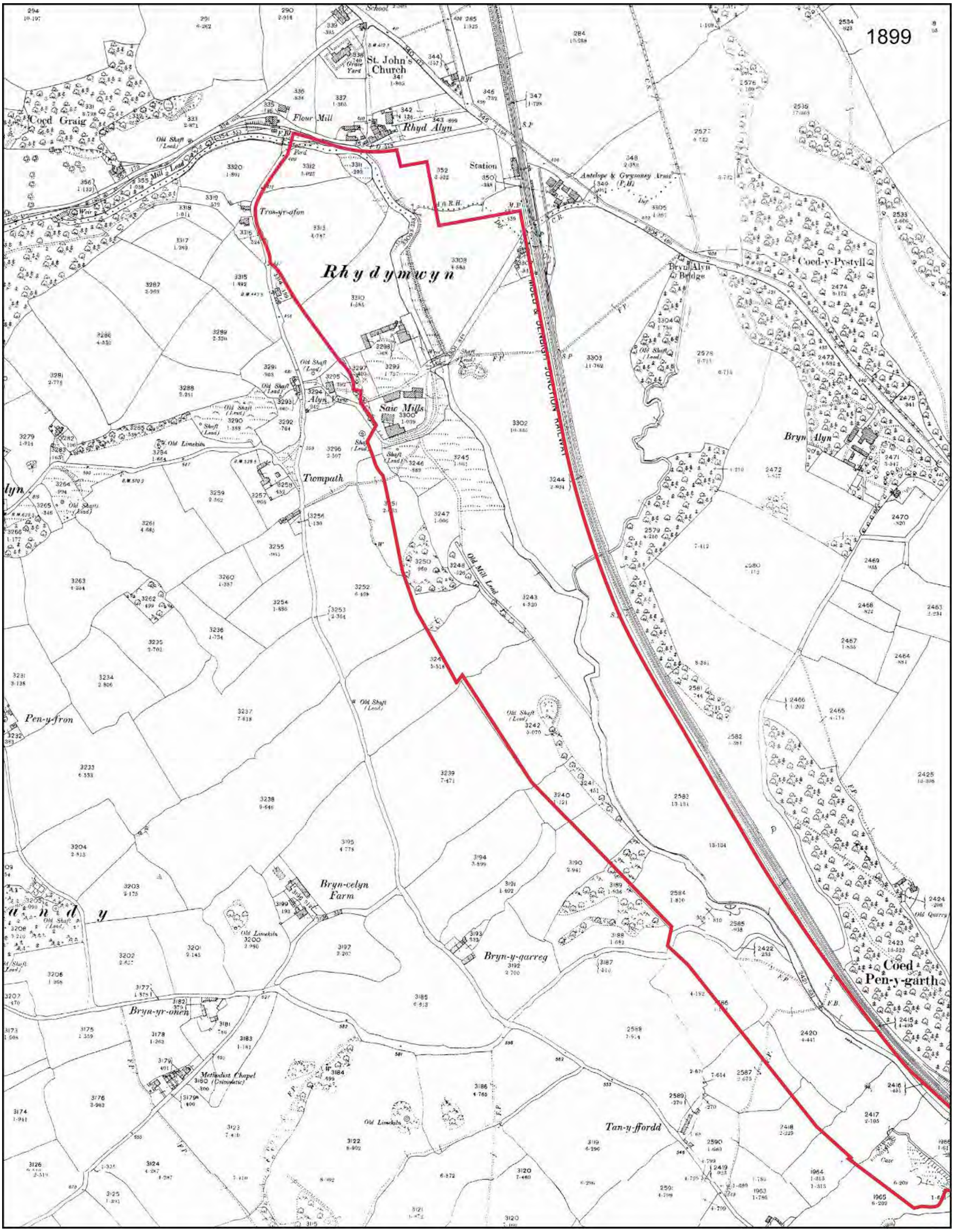


Figure 5 Second Edition Ordnance Survey Map

Other documentary records reveal that Brunner Mond & Co Ltd operated on the site for a brief period between 1900 and 1902 (CPAT SMR 18034). The company was formed in 1873 when John Brunner and Ludwig Mond built the Winnington Works at Northwich, Cheshire (brunnermond.com). They started producing Soda Ash in 1874, which was widely used and had many applications in the nascent pharmaceuticals and chemical industries as well as the glass industry. They also developed a method of processing Zinc ore, which is probably what was done at Rhydymwyn. This company later became one of the founder parties of Imperial Chemical Industries (I.C.I.), which would have a hand in the development of the site during WWII (see below).

The later Third Edition Ordnance Survey Map, surveyed in 1912, reveals that the site of the earlier foundry had been taken over by the 'South Halkyn & Rhydymwyn Mine (Lead)' (Figure 6 below). The two shafts that had been sunk by 1900 immediately east and southwest of the old foundry were still being worked. However, the main thrust of mining operations at this time appears to be from the reopening of Davey's Shafts on the hillside overlooking the valley. A single track inclined plane or tramway is shown connecting the pit heads with the dressing floors on the valley bottom (this is still visible as an earthwork on the ground SMR 98053). At the base of the incline plane is a small structure, probably an engine house, and a large waste tip (SMR 98054 and SMR 98055 see Appendix II). To the east, workings at the head of the Brick Iron Shaft had also expanded by this time. The leats that had been allowed to silt up during the complex's period as a saw mill were re-opened by the mine owners, and with the restoration of the water supply it is probable that a waterwheel may have been re-employed to drive a crusher on the dressing floor. To the south the course of the former leat adjacent to Wheel Shaft survived, as did the old mill lead (leat) shown emerging from underground; spoil heaps were also shown near the Wheel Shaft. It is probably from this episode of increased activity that the area of tips and possible mine shafts to the south of the incline plane probably date (SMR 98056, Appendix II). Due to the concentration of mining features within this discreet area it was not possible as part of the current survey to identify each feature individually, it is therefore recommended that further more intensive survey be undertaken on this area of the site. However, several possible mine shafts were noted, as well as tip heaps and dumps of ash and clinker which may represent rake-out from the engine used to power the incline plane.

Further south, the walkover survey identified a rectangular structure that is not depicted in the cartographic record (SMR 98059, Appendix II). It is of dry stone wall construction, as are many of the other stone-built features across the site. The western elevation still survives to a height of around 1m, and although there are substantial areas of collapse, it is possible to make out four walls. It occupies a site that has been terraced out of the hillside, with a revetment wall built out of the hillside to increase the floor area. A quantity of pottery was recovered from where the pathway of the recently constructed woodland walk cut through the outer terrace wall, these sherds have been spot dated by Stephanie Rátkai, and appear in Table 3 below. The dates range from the 18th century to the first half of the 19th century, which is when much of the mining was undertaken in the vicinity of the site. However, the exact function of the structure remains unknown, and it is likely that this will only ever be resolved through proper archaeological excavation of the site.

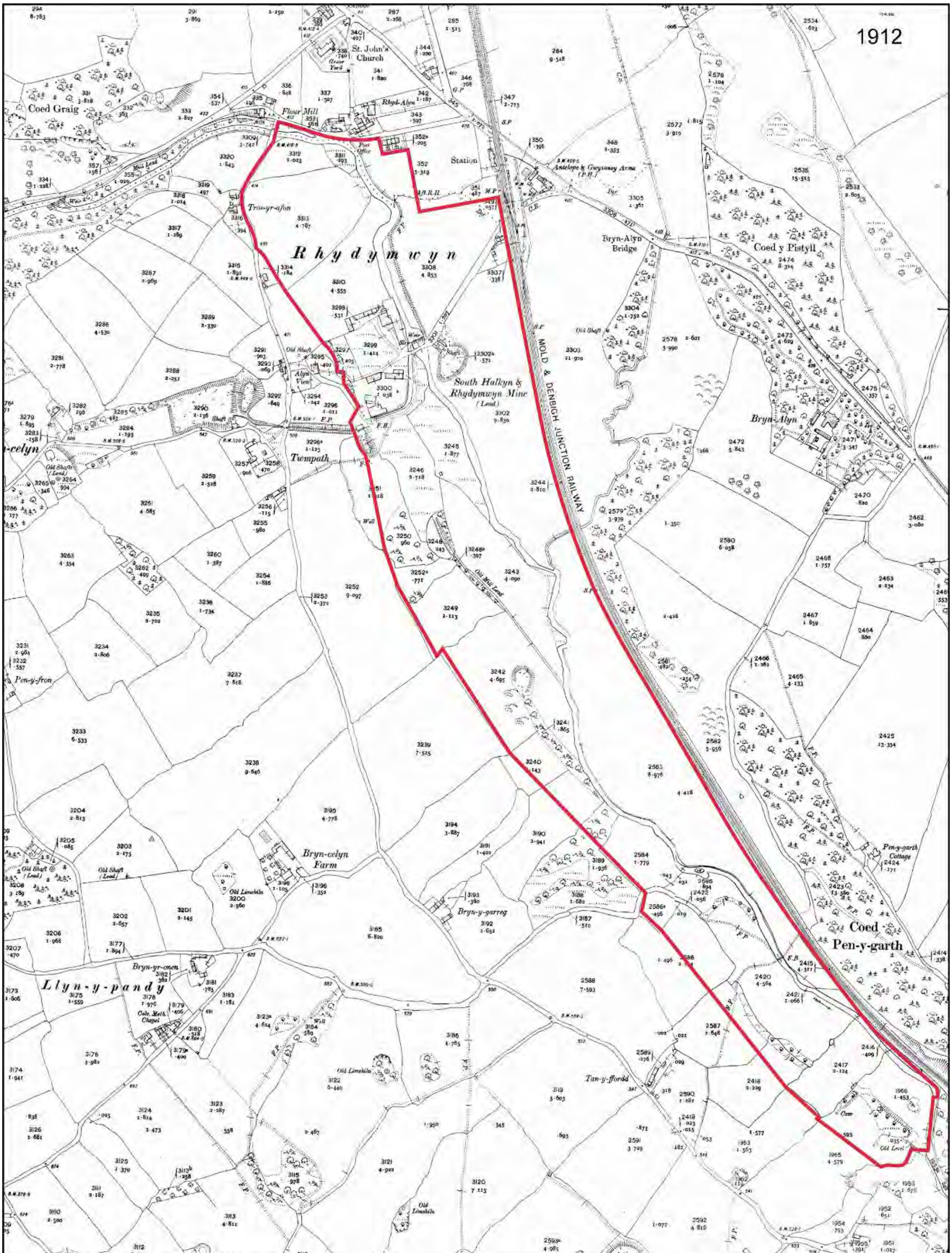


Figure 6 Third Edition Ordnance Survey Map

Type	qty	Date
blue shell-edge plate	1	e 19th c
light-on-dark trailed slipware bowl	1	18th c
industrial slipware bowl and ?jug/jar	2	e 19th c
painted ware cup	1	1830s-1840s
creamware hemispherical bowl	1	late 18th c
brown salt-glazed stoneware knob from lid	1	18th c
pearlware blue transfer printed foot-ring bowl base	1	1830s-1840s
blue transfer printed jug handle	1	1830s-1840s
blue transfer printed ware plate	1	?first half of 19th c
blue transfer printed ware plate	1	19th c
embossed painted pearlware plate	1	19th c
light-on-dark trailed slipware bowl	1	18th c
light-on-dark trailed slipware	3	18th c
light-on-dark trailed slipware bowl	1	18th c
light-on-dark trailed slipware bowl/dish base	1	18th c
clay pipe stem	2	
utilitarian ware black glaze	9	18th c or later
utilitarian ware mid-brown glaze	13	18th c or later
coarseware	1	18th c or later
agate ware?	1	18th c
utilitarian ware black glaze flange-rim bowl	1	18th c or later
utilitarian ware black glaze bowl	1	18th c or later
utilitarian ware black glaze bowl	1	18th c or later

Table 3 Pottery spot dates

The site continued to be used for processing and treating lead ore from local mines until at least 1921 and on abandonment the Brick Iron Shaft was about 110 m deep, and connected at its base with a vein drive from the Milwr Tunnel (Cruickshank 1996b, 6).

A plan dated 1925-27 for a proposed new housing estate in the village (held at the National Archives Kew) describes the early foundry site as a disused Lead Mine. It shows the former works buildings, marshy ground, the weir and the bridge, as per the Third Edition (1912) Ordnance Survey Map.

In 1939 the site was acquired by the Ministry of Supply for the construction of a chemical weapons production plant and storage facility (Figure 7 below), and, for later editions of the Ordnance Survey mapping data for the site as it was surveyed for the production of the Third Edition continued to be used. This was most likely to be a deliberate attempt to disguise the size and function of the site, and there would also have been problems with access. Even as late as 1967 the post-1938 development of the site was still being obscured by the reproduction of the 1912 data.

Lead mining was suspended during the Second World War throughout Wales, and where it did recommence in the post-war period it was usually combined with other concerns, such as limestone extraction for agricultural purposes, as witnessed at the Halkyn Mine (Walters in Jones et al 2004, 25). The site at Rhydymwyn, however, followed a different, more unusual tack after it was acquired in 1938/39 by the Ministry of Supply.

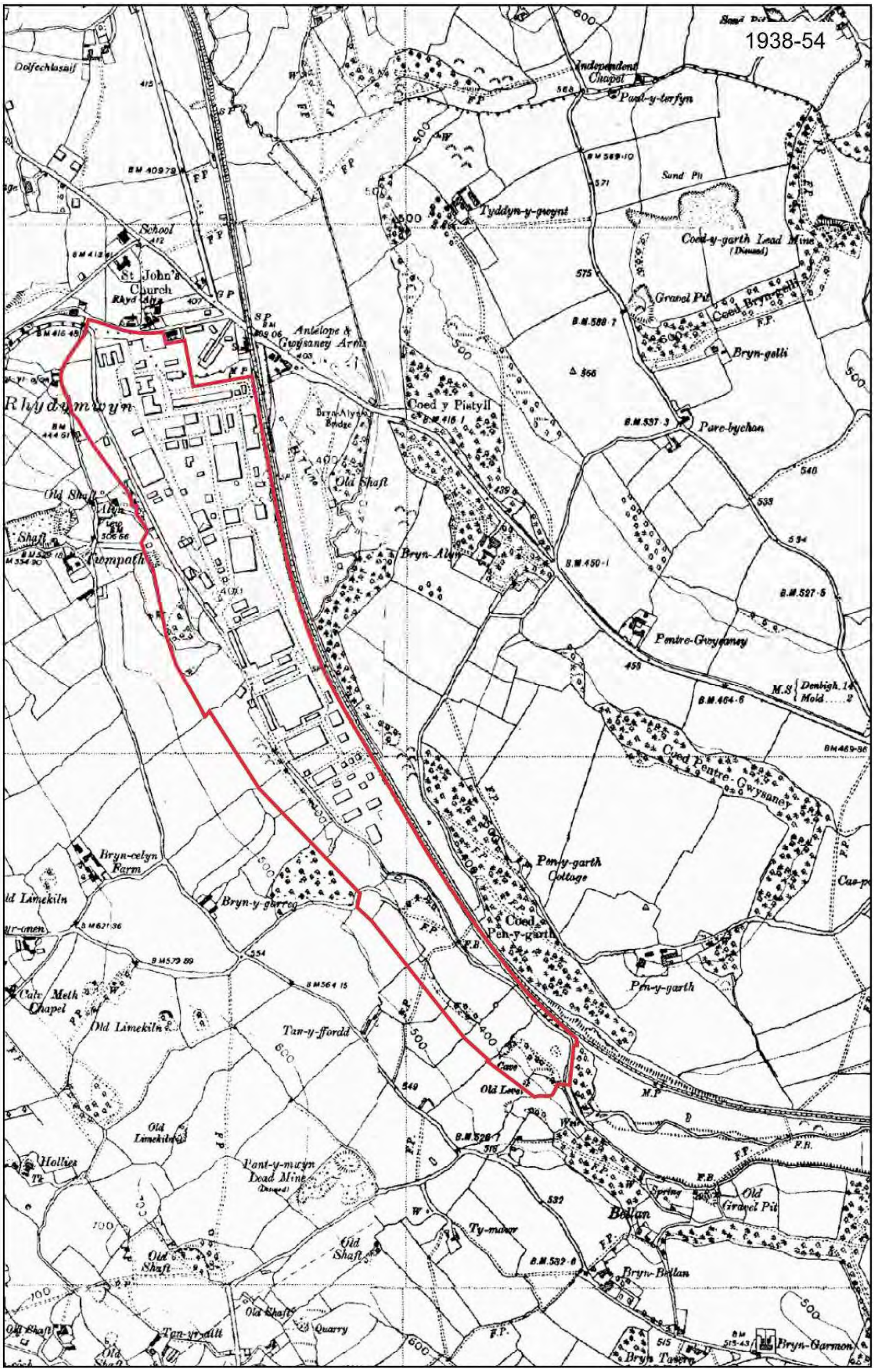

1938-54
Dolfechlasaif
School
St John's Church
Rhydymwyn
Antelope & Gwysaney Arms
Bryn Alyn Bridge
Old Shaft
Cwmpath
Coed y Pistyll
Tyddyn-y-gwynt
Independent Chapel
Pant-y-torfyn
Sand Pit
Coed-y-garth Lead Mine
Gravel Pit
Coed Bryn-golli
Bryn-golli
Parc-bychan
Bryn-Alyn
Pentre-Gwysaney
Coed Pentre-Gwysaney
Pen-y-garth Cottage
Coed Pen-y-garth
Pen-y-garth
Bryn-celyn Farm
Old Limekiln
Bryn-y-garreg
Calv. Meth. Chapel
Tan-y-fford
Old Level
Cave
Old Limekiln
Pant-y-mwyn Lead Mine
Hollies
Ty-mawr
Bryn-Bellan
Bellan
Old Gravel Pit
Old Shaft
Quarry
Tan-yr-allt
Bryn Tawr
Bryn-Garmon

Figure 7

CHAPTER 3 A BRIEF HISTORY OF CHEMICAL WARFARE

Kirsty Nichol and Professor Timothy Peters

3.1 The Great War (1914-19)

On the 22nd April 1915, without Warning, the Algerian Division of the French Army at Ypres was attacked with 150 tons of chlorine gas over a four mile long front. The effects were devastating and the front collapsed. Two days later, on the 24th April, the then uncovered flank of the 2nd Canadian Brigade was similarly attacked. Thus began modern Chemical Warfare.

Professor Brereton Baker and the famous physiologist Dr. J.B.S. Haldane were immediately dispatched to the war zone to identify the gas used and to recommend antidotes and counter measures (TNA WO 142/281). In parallel, scientists throughout the UK were mobilised to develop retaliatory measures including novel gases and chemicals. Thus, Professor Gibson of Guy's Hospital started a programme on arsenical gases (Diphenyl chloroarsine) and smokes including the development of effective respirators (TNA WO 188/80). These experiments led to the development of lachrymatory agents (Tear Gas). There were proposals to manufacture Diphenyl Cyanarsine at MS Valley and a contract was sanctioned for the construction of a plant capable of producing 15 tons per week at a cost of £165,000 in December 1940. The project was later abandoned although charging with D.C. produced elsewhere continued (TNA SUPP 5/1003).

The use of Hydrogen sulphide was investigated by John Cadman, Professor of Mining at Birmingham University, but it was found to be unsuitable due to its dangerous flammability, corrosive nature, low density and distinctive smell at low concentrations which would allow for early detection. Professor Sir James Irvine FRS of the University of St Andrews, and colleagues, worked on the preparation of a series of derivatives of hydrogen sulphide leading to the production of Mustard 'Gas' (Dicloroethyl Sulphide) by the Castner Keller Co. of Runcorn (TNA WO 142/196).

Meanwhile, the Royal Engineers were planning a retaliatory attack against the Germans. Both the Army and civilian population were scoured for individuals with knowledge of chemistry, although knowledge of plumbing would perhaps have been more appropriate. They were formed into Special Companies under the leadership of Major C.H. Foulkes and trained in gas warfare (TNA WO 142/335). Their special duties ensured that they were all promoted to the rank of corporal, and they jocularly became known as the 'Comical Chemical Corporals'. On the 25th of September 1915 at the Battle of Loos the first British counter attack with gas occurred with a total of 68 tons of chlorine in some 2,500 cylinders. In sections of the Front where the wind direction was favourable, the subsequent infantry attack was successful. In the following months further developments took place with phosgene being used as the principal gas. However, it soon became apparent that gas was not an easy weapon to deal with as it was difficult to handle, it relied on a favourable wind direction and was rapidly dispersed, this resulted in there being the constant risk of injury to ones own troops.

Next, there were moves to develop gas shells, grenades and mortars and suitable agents including smoke canisters, incendiary devices and more potent agents. Improvisation was the order of the day. For this reason, early experiments were conducted by Jocelyn Thorpe, Professor of Organic Chemistry at Imperial College, London with Captain F.V. Lister, a civil engineer from Liverpool, in a single room in a small isolated cottage in Wembley. Together they made the chemicals, filled the shells and tested them in an adjoining field (TNA WO 142/244). The unit expanded to form the Chemical Projectile Laboratory with testing being carried out at the recently established Porton Down facility by 1916.

Following the use of gas warfare by the Germans, and the decision by the British to retaliate-in-kind, it was rapidly realised that the UK lacked a well-founded chemical industry capable of manufacturing the necessary agents. The expertise and production units for many chemicals resided in Germany and, for too long, training in chemical research had only been available there. Reference has already been made to Professor (later Sir) Jocelyn Thorpe FRS (1872-1939) and his pioneering work on gas shells. He trained as an undergraduate in engineering (Kings College, London) and in chemistry (Royal College of Science, South Kensington) in Britain. However, for his research training (PhD) he went to the University of Heidelberg, and also spent time in a dye works in Germany gaining experience in industrial organic chemistry before returning to the University of Manchester in 1895. He was appointed Professor of Organic Chemistry at Imperial College London in 1913 (Ingold, 1941).

This undue reliance on Germany for training in chemical research and the UK's dependence on the German chemical industry for its products were instrumental in the post-war formation of Imperial Chemical Industries (I.C.I.) who rapidly developed a world wide reputation that persists to the present. In the early 1930s I.C.I. were not linked to CW production, but their experience in dyestuffs was closely linked to the expertise necessary to produce explosives and CW.

The use of Mustard Gas, originally called 'Mustard Oil', by the Germans for the first time in 1917, against Canadian soldiers and later against the French at Ypres, heralded a further escalation in the chemical warfare (CW) race. The highly reactive mustard is rapidly absorbed though the skin causing either rapid cell death in a variety of organs or, in the longer-term, DNA mutations and malignancies. The laboratory synthesis of sulphur mustard was first reported in 1860 but further developments were necessary to prepare the material on a commercial scale. The German Company Bayer developed a process for mass-producing mustard and the British developed a process for making mustard from ethylene and sulphur dichloride. It was successfully used in the attacks on the Hindenberg Line in September 1918.

After the war Lister collected detailed drawings of some 185 different projectiles now deposited in the National Archives (TNA WO 142/221). A close colleague was Major Livens MC who developed a simple mortar which continued to be used up to the early days of WWII. The Livens Projector was capable of delivering several thousand 'drums' of phosgene some 2,000 metres into the enemy lines. Captured German documents confirm the efficacy of these weapons and they complained that the Allies were "violating the laws of gas warfare"! In 1918 Foulkes was also experimenting with 'Gas Beam Attack' using cylinders, mounted on railway tracks which ran parallel to the German lines, which could be released when the wind direction was correct. In ten such attacks 27,000 cylinders were released in this way (Holmes 2004).

In his collection of essays entitled 'Disenchantment', which were published after the war, Charles Montague (propaganda writer for the British Army 1916-18) describes one such gas attack:

> 'Horses and tethered cattle were startled and tugged at their head ropes. A little dog on a heavy chain, unable to scramble onto the roof of his kennel ran about frantically; hens flew onto walls and outhouses, clucking loudly; little chicken stood on tiptoe, craning to raise their gaping beaks above the vapour; mice came out of the holes, one climbed the gable of the barn only to fall back when near the top. Seedling peas and other vegetables were bleached and wilted'
>
> (C.E. Montague 1922, 108)

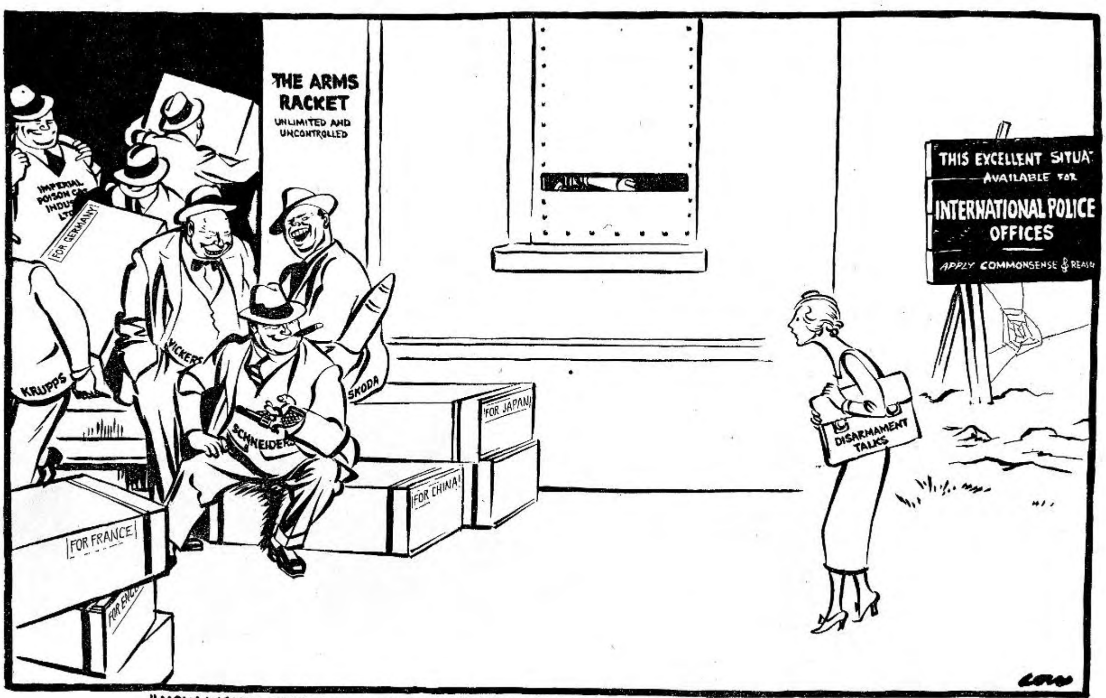
In his history of Porton Down, L. Col. Kent comments that 'it is likely that the Germans wished, as time went on, that they had never started this form of warfare' (Kent 1960, 28).

During this period most munitions industries were located in the traditional metal working and shipbuilding areas of the country – the Midlands, the north of England and Scotland – as well as the naval dockyards of the south. However, during the 1930s many munitions factories were relocated to the west of England and Wales to lessen the risk of air attack. This threat also resulted in major efforts to construct underground munitions stores in Britain (Schofield 2004, 10).

3.2 The Development of Chemical Weapon (CW) Production in World War II

Appeasement and rearmament went hand in hand to a greater extent than is commonly realised. From 1934 a decision was made to rearm but it was a difficult economic balancing act, the economy being seen as the fourth arm of defence after the RAF, Navy and Army. The RAF and Air Defence had top priority. This was a long-term plan, with the RAF actually preparing for war with Germany in 1939, which enabled the most up-to-date generation of aircraft, such as the Supermarine Spitfire and the Wellington bomber to be developed just before war was declared.

During the interwar years the public fear of aerial bombardment and gas attack far outran the technical ability to deliver this type of horror. This fear was fed by books such as Gulio Douhets 'Il Dominio dell'aria' (1921), J.F.C. Fuller's 'The Reformation of War' (1923), Neil Bell's poison gas novel 'Valiant Clay' (1934), and the Italian gas bombing in Ethiopia in 1936. Stanley Baldwin - the Prime Minister best known for the maxim that 'the bomber will always get through' - also declared that 'the next war will be the end of civilisation in Europe', while Harold Macmillan later said that 'we thought of air warfare in 1938 rather as people think of nuclear warfare today'. During this time much of the emphasis was on defence against CW's, and, following the horrors experienced in the Great War the League of Nations negotiated the prohibition of gas (and biological) warfare in 1925 in the Geneva Protocol; however, this was never ratified by Japan.



"NOW WOULD BE THE TIME TO CALL THE POLICE, KID—HUH, HUH!—IF THERE WERE ANY POLICE."

Cartoon by David Low by arrangement with the Trustees and the London *Evening Standard*

However, in the run up to World War II there was a much more technocratic approach to munitions production. In 1936 a ministry for the Co-ordination of Defence was set up. Defence spending rose consistently year on year such that by 1939 nearly half of government revenue was spent on rearmament. This situation actually weakened British room for manoeuvre in the negotiations over Poland in the run up to war, and, ultimately, had bankrupted the British economy by 1940-1.

British research was concentrated at Sutton Oak, St. Helens (agent production) and Porton Down (chemical defence). Much of the research was directed at developing more effective respirators and other forms of protection particularly against the newer agents. At a meeting on 29th January 1937 between Vice-Admiral Sir Harold Brown (Director General of Munitions Production) and significant members of I.C.I., it was decided that the Randle site, just outside Runcorn, should be used to produce Mustard Gas (Toler 1993, 14). So began Britain's preparations for a full scale chemical war with Germany. Between 1937 and 1942 twelve chemical defence factories were approved, at a cost of nearly £11m for buildings and £8.3m for plant, making this category of munitions production the most costly at £19.2m. Filling factories were the next most expensive at £15.8m for 6 factories (these were generally much larger than the production sites), whilst shell and fuse production was limited to 7 factories and cost £2.1m. All chemical weapons factories were agency managed, the majority (six) by I.C.I. (Hornby 1958, 158).

These factories were managed by I.C.I. for the Ministry of Supply under agency agreements, thus ensuring that there was no opportunity for seemingly blood-stained profits to be linked back to Government agencies, but also ensuring that there would be no risk of post-war losses. I.C.I. undertook this work in a somewhat public-spirited way, with fees for construction and management of agency factories being negotiated and representing something of a good bargain for the government. In 1941 there was a flat fee of 1% on construction work and management fees were 0.5%. By 1942 two I.C.I. directors, five chairmen and directors of groups, and thirty three other staff (including fifteen chemists) had been seconded to Ministries, as well as 3,345 trained staff being sent to run government factories, including the Tube Alloys project (Reader 1975, 255).

	Plant	Start date	Gov money	World War II construction fee
Toxic products	Randle	April 1938	£2,502,544	£64,850
	Valley	January 1941	£3,161,671	£80,000
	Springfields	Feb 1942	£2,624,061	£26,143
Intermediates	Rocksavage	Sept 1939	£2,378,645	£52,381
	Wade	April 1940	£1,318,103	£13,055
	Hillhouse	June 1941	£4,777,365	£45,947

Table 4 Showing costs of CW plants (Source: Government Construction Contracts 30 Sept 1943 submitted to Gov. Contracts. Committee)

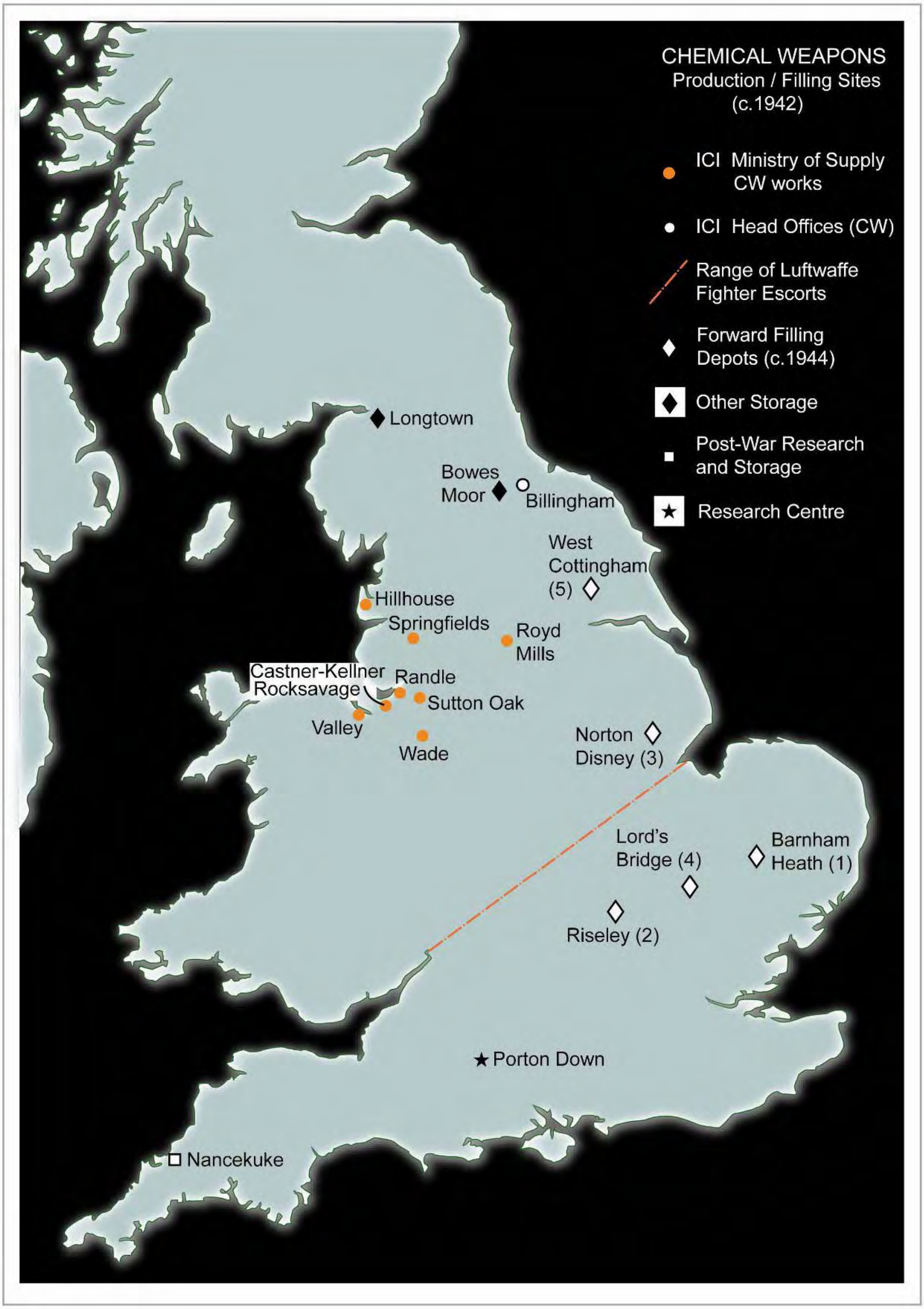


Figure 8 Chemical Weapons production/filling sites

Tube Alloys was an invented name (like the tank in the Great War) to cast a screen of vague and not very interesting credibility about the whole project. By June 1944 the government had authorised I.C.I. to spend £950,000 on tube alloys research, this was a hefty proportion of all spending on research which was a little over £1.5m (Research Expenditure on behalf of the government Statement 30 June 1944 CR 93/5/820 Central Registry papers I.C.I. Head Office Records Centre in Reader 1975, 287).

There was a general public phobia regarding the risk of air raids and gas attack (with gas masks being issued to all), and retaliation was accepted, with little faith being stored in the various declarations against it. Deterrent demanded that gas be made. However, few stockpiles of chemical weapons had been made and in September 1939, when the BEF (British Expeditionary Force) embarked for the Continent, although it was well provided with anti-gas equipment, our forces had only a very limited capability to retaliate in kind if the Germans had used chemical weapons.

3.3 The Establishment of M.S. Valley Site

In 1938 the government requested that I.C.I. look into the siting of a new chemical weapons plant that would be capable of storing up to 1,500 tons of Pyro and Runcol, preferably in underground storage facilities and, where possible, to make use of existing mines and tunnels. As well as subterranean storage facilities it was a prerequisite that the site have sufficient room for charging sheds, and enough for later expansion into manufacturing of the chemicals themselves.

Criteria for the choice of site:

- Subterranean storage facilities capable of holding 1,500 tons of Pyro and Runcol.
- Room for expansion to include charging sheds and eventually manufacture of Pyro and Runcol.
- Proximity to Randle.
- Good road and rail links.
- Good water supply and effluent disposal.
- Concealment from air and sea attack.

A shortlist of several sites was drawn up for consideration, these included Meadowbank Salt Mine, Winsford, Penny's Lane Mine, Northwich, and a disused copper mine at Alderley Edge. These were all found to be unsuitable either due to lack of space for manufacturing, or danger of collapse of the mines themselves. Proposed sites in Derbyshire were similarly disregarded due to problems of water supply and effluent disposal, as well as difficult wintertime weather conditions. As discussions developed, it became clear that a site with links to tidal waters was necessary, and this refocused attention around the estuaries of northwestern England. Two sites near Morcambe (Grange and Haversham) were dismissed as they were considered to lie too far from Runcorn (the Randle site). Sites at Llanrwst, Llandulas and Rhydymwyn were considered to fulfil most of the criteria outlined above, with the latter being the best suited (Ferguson 1939, 2).

Further to this selection process a borehole survey was undertaken in late 1938. This revealed that the underlying subsoil of the valley bottom at Rhydymwyn was suitable for the construction of the manufacturing buildings without the need to pile their foundations. Input from the local mining engineer also confirmed that the underlying limestone strata was suitable for tunnelling safely (ibid). It was also observed that the route from Runcorn (the Randle site) to Rhydymwyn avoided major centres of population, and it was further established that it would be relatively easy to close the road from Mold to Rhydymwyn during the construction and initial stocking of the facility (Ferguson 1939, 4).

In terms of concealment, an attack on Rhydymwyn from the sea was impossible, and the proposed site lay outside the route from mainland Europe to the Liverpool – Manchester industrial corridor which had been identified as a probable bombing target. Further to this the site lay in a wooded valley, very similar to many others in the area, which would have made finding it more difficult. Therefore, unless there was German intelligence for the site and they actually knew of its existence, and where to look for it, targeted attack from the air was made more unlikely (Group Captain (JARIC) Nigel Pearson pers. comm.). The site was constructed with aerial bombardment and reconnaissance in mind, the design meant that individual processes took place within a single building, which had the effect of making the facility appear much less like a chemical plant when viewed from the air, thus preserving its anonymity from stray bombers. Furthermore, much of the site was also concealed from the road, and was therefore unlikely to come to the attention of passing German agents or sympathisers. In fact, there is no known evidence that Germany ever identified the M.S. Valley site as being of strategic importance, nor of it ever being a target.

Criteria	**The Valley Site**
Subterranean storage facilities capable of holding 1,500 tons of Pyro and Runcol	Steep hillside along the western side of the valley which could support the necessary cubic feet of tunnels.
Room for expansion to include charging sheds and eventually manufacture of Pyro and Runcol	Potentially 60 acres of suitable land available
Proximity to Randle	Distance: 30 miles
Good road and rail links.	Routeways largely pass through open countryside. No severe hills en route. The main road passes directly the northern corner of the site. Double track L.M.S line passes along the eastern side of the site, which is little used.
Services (Good water supply and effluent disposal)	In wet periods water can be obtained from the River Alyn. In drought water can be taken from disused mine workings in the vicinity. District already supplied by the North Wales Power Company. Tidal estuary 5 miles.
Concealment from air and sea attack	The valley is wooded and is not outstanding from its neighbours. The village is small, population of only c.200, and therefore no obvious target.

Table 5 Criteria for the choice of site

Thus the site at Rhydymwyn was eventually chosen, with the development of the facility being planned in two phases. Phase I involved the cutting of the underground storage caverns. They were designed to hold 1,500 tons of Pyro and Runcol in bulk, fused 30lb bombs as well as bonded and charged weapons, and to accommodate charging facilities and assembly unit magazines. Other necessary infrastructure and enabling works, such as offices, canteen, and services (including boiler house, electrical substation, transport, and water supply), were also included in this phase of development. Phase II involved the construction of the Pyro and Runcol manufacturing facilities as well as storage facilities for raw materials (oil and alcohol), mixing plants and furnaces, and laboratories (Ferguson 1939, 3-4).

3.4 Development of the site

Unlike other factory sites such as Randle, where the chemicals industry was well established and buildings already existed, the green field site at Rhydymwyn presented the opportunity to design and create a purpose-built facility. The site was therefore divided into distinct and separate zones characterised by the activities or processed being undertaken within them (Figure 9 below). This also helped to ensure that cross-contamination between areas and processes was kept to a minimum, and that secrecy between different departments was maintained.

Administration and Stores

The administration buildings were all clustered around the main entrance to the site, and comprised offices and a bicycle park. There were stringent rules and regulations relating to visitors to the site, and personnel were checked in and out rigorously.

Process Area

The production buildings were all located at the northern end of the site, at the beginning of the system of flows around the factory. Originally there were to have been five production buildings, but one was taken over for the Tube Alloys project, and one has since been demolished. It is these four surviving buildings that dominate and characterise this area of the site today. The buildings themselves were interspersed with ancillary and ARP buildings, and from 1944 were interconnected by a network of toxic drains and pipes that pumped Runcol and possibly Pyro around the plant. Prior to this, tanks attached to trailers were used to move the liquid up to the filling stations and storage areas.

Laboratories

Safety testing, quality control and CW development took place here.

Antelope Field

The field adjacent to the site was used for storage.

Charging Area

The charging (or filling) of shells was undertaken in large buildings situated around the entrances to the tunnel complex. These have since been removed.

Danger (Assembly) Area

Once the shells had been filled they needed to be armed, this was undertaken in what became (and is still known as) the Danger Area. The Magazines where the fuses explosive bursters were stored were located at a distance from the main complex of buildings for safety reasons. They were hidden away on the hillside overlooking the western side of the valley, and protected by large heavily reinforced concrete blast walls. Once the shells had been armed they were either stored in four buildings to the south of the main complex of buildings in the Danger Area so that they could be shipped out by rail, or they were taken back to the tunnels.

The Western Bank

Where the majority of the ARP structures were constructed and where one of the emergency exits for the whole facility was located. Also, the location of the Magazines because they could be cut into the hillside to give added protection from enemy bombing, and isolated if there was an accident.

Underground Stores

The principle storage area for the factory was a series of rock-cut caverns which were cut into the steep hillside on the western side of the valley. As well as Antelope Field which was also used for storage, a third area, some five miles distant, known as Woodside, was also used. This reverted to agricultural usage shortly after the War.

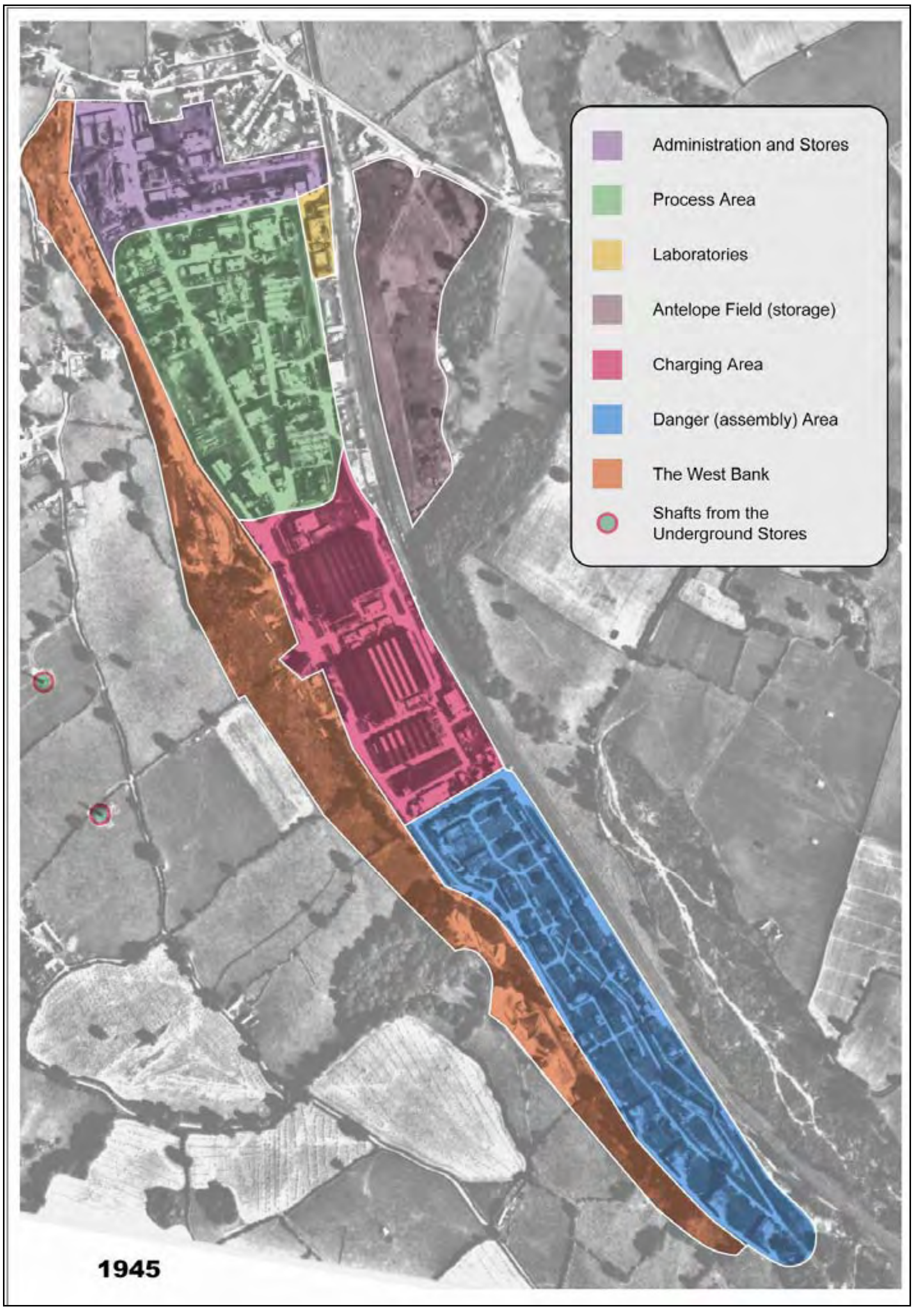


Figure 9 Subdivisions within the factory

M.S. Valley did not exist purely in isolation, other CW sites were producing chemical weapons across the UK, and others acted as storage facilities and forward filling stations (Figure 8 above).

Site Name	Location	Chemical Agent
Randle	Runcorn	Mustard
Sutton Oak	Runcorn	Experimental Plant
Rocksavage Works	Runcorn	Chlorine Bleaching Powder (decontamination of mustard) Phosgene
Wade Works	Northwich	Chlorine Bleaching Powder Alloprene (chlorinated rubber)
Royd Mills	Huddersfield	Glycol
Springfields	Preston	Mustard Lewisite Larmine (Bromo Benzyl Cyanide – Tear Gas)
Hillhouse	Fleetwood	Chlorine

Table 6 Other Ministry Factories

3.5 Wartime Production

> ‘The possible use and counter-use of poison gas, if invasion should come in the New Year, weighs heavily upon me’
>
> Winston Churchill 1940

During December 1939 and January 1940 Anglo-French aerial trials using mustard were carried out over the Sahara Desert, Algeria. The trials revealed that the most widespread contamination could be attained by spraying mustard from a height of 15,000 feet or more, which resulted in total (100%) contamination of all personnel and equipment not under cover (Thomas 1985, 48). The strength of feeling against the use of spraying enemy troops is witnessed in the minutes of a meeting held on 19th April 1940 between representatives from the War Office and the Air Ministry:

‘High spray is necessarily an indiscriminate weapon, and demands extremely correct meteorological information, together with a reasonably high standard of training if the spray is to be delivered on the objective. Even though the spray be directed against concentrations of troops it is certain to affect civilians in or near the area attacked. It is considered most undesirable from the political point of view to adopt this form of warfare, at any rate until the enemy have used it extensively against us. It is understood, however, that the accepted view of HM Government at the present time is that no form of gas warfare will be used until it is first adopted by the enemy'
(TNA WO 106/1627).

Following Operation Dynamo in June 1940, during which some 338,000+ personnel of the BEF and French Armies were evacuated from Dunkirk, the threat of invasion seemed imminent. It was at this time that production of Pyro at Randle and Springfield was stepped up, and the RAF’s Lysanders, Blenheims and Battles underwent conversion to carry 250lb and 500lb bombs and containers of Mustard that could be used to spray the landing beaches. In the event of invasion ‘chemical lorries’ (large tanks fitted with a spraying device) would also have been deployed to spray transport corridors, thus denying them to the enemy (Toler 1993, 15). Gas bombs were also to be distributed, and a squadron of Wellington bombers trained in their deployment (Thomas 1985, 54). Its use on the landing beaches to slow the enemy was discussed in detail at the time, and it was concluded that gas would ‘prove a potent weapon for delaying the enemy at the points of landing’ (TNA AIR 2/5117).

In subsequent discussions between the RAF and Bomber Command, it became clear that aerial bombing, rather than shelling was the preferred method of delivery. Mainly on the grounds of it delivering more effectively the full dose of contamination, as well as allowing greater accuracy in its delivery.

Aircraft Type	Shell Type	Airbases for Deployment
Lysander	250lb	Grangemouth York Sawbridgeworth Gatwick Tilshead
Blenheim	500lb	West Raynham Watton Swanton Morely Horsham St Faith Wattisham
Wellington	1,000lb	Feltwell Honington Newton Binbrook

Table 7 Showing the 'Gas Plan' revised in November for 1940 for the deployment of CW in the event of invasion.

Later in 1940 mustard was transported to the Middle East, to be used, if necessary, against the Italians who had used it in Ethiopia. Plans were also set in motion for production to be moved to South Africa in the event of sites in Britain being disabled (Toler 1993, 15). MS Valley went into production of mustard gas in 1941, with somewhere in the region of 15,500 tons being produced during the wartime period (all using the Runcol process, see Bone below). Pyro production, although originally planned for the facility, was ultimately never undertaken on the site. This allowed one of the Pyro buildings (P4) to be used by the Tube Alloys (uranium enrichment) project instead (Pearson 1996, iii). Production on site included, as originally designed, the manufacture, filling and charging of weapons, as well as their storage, and in 1942 it was decided to expand production to Smoke Generators as well as chemical-filled munitions (Madel 1945, 2).

In 1941 the British Chiefs of Staff were asked to investigate the preparedness of the Army and RAF to fight a chemical War. The Ministry of Supply were able to report in March 1941 that there was a shortfall in the production of the 25-pounder for the army, and that Phosgene supplies were also low (but could be supplemented with supplies from the US), but that production of mustard had in fact been over provided.

In April 1942 the British Chiefs of Staff presented the results of a review they had undertaken into Britain's ability to fight a chemical War. It concluded that in Europe, India and Burma, and the Middle East, Britain would not be able to sustain a chemical War due to the lack of protection of the civilian population. At the same time the army undertook their own investigations into their chemical weapons capability. They concluded similarly, that on the several fronts on which they were fighting, particularly those in the Western Desert, the effective use of chemical weapons was very limited (Thomas 1985, 58). In response to this, the War Office reduced the priority previously given to offensive gas production.

In 1943 mustard was sent to Malaya in response to the Japanese's use of it against China. The Allies considered its use in sub-tropical environments at this time, and in November 1943 Major General Lethbridge presented an interim report that concluded that a 'ruthless application of chemical Warfare under tropical conditions will produce destruction and desolation upon a scale scarcely surpassed in the history of War' (Thomas 1985, 62, TNA WO 106/459A). During 1943-4 the production of mustard at the Randle factory ceased temporarily. However, all members of staff were retained so that production could recommence given 24 hours notice if necessary (Toler 1993, 20).

By 1943 it was thought that the stockpile of chemical weapons held across the UK was a sufficient deterrent. However, consideration of their retaliatory use against Hitler's Vengeance Weapons as part of the research behind Operation Crossbow led to recommencement of production in 1944. The background to this probably lay in a memo to Major General L.R. Groves, dated 20th April 1944, from W.S. Parsons (U.S.N.) in which the possibilities of the German development of a new 'dirty' V-weapon were discussed. During a meeting at the Pentagon on 14th March 1944, Parsons was made privy to new intelligence regarding rocket installations under construction in northern France at the time. He reported that several of the larger stations were 'guarded with great energy' and was concerned at their location within 100-150 miles of London and Bristol. He goes on to say that:

> 'At the time [he] could form no opinion as to the possible nature of the contemplated material except that it must be a very "hot" chemical since the installations were literally under the guns and bombs of the enemy, the opposite place to where a delicate chemical job should be performed.'

He then reported that he had been in discussions with Chadwick's group from Britain about the possibilities of evolving radioactive poisons which could then be used as a weapon. These discussions had led him to believe that this process 'would not be extremely difficult to set up and operate and that it could be "milked" every three days'. His final paragraph, was perhaps the most chilling of the memo;

> 'The combination of an apparent plan to use unmanned aircraft and the possibility that some form of complicated installation is being built in locations which might serve as feeders to the launching point, suggests the possibility that the "hot chemical" might be radioactive disintegration products which the Germans considered so "hot" that they could not transport them from manufacturing points in Germany by any available transportation. These might be placed in bombs with ordinary explosives to be functioned over the ground to gain maximum distribution of the radioactive products. It is unnecessary to picture the destructive possibilities of such an arrangement'

The details of this memo perhaps go some way to explaining the sudden rise in production of mustard at Rhydymyn in the summer of 1944 following the D-Day landings. Ultimately, however, chemical warfare was once again rejected as being too high a price to pay, it seems we had all learnt, in retrospect, the lessons of the Great War.

Factory	Maximum theoretical output per week (in tons)			
	Runcol (HT)	Pyro (HS)	Phosgene (CG)	Larmine (BBC)
Randle	100	160		25
Rocksavage			57	
Springfields		308		
Valley	110	240		
Total	210	608	57	25

Table 8 Figures calculated from Factory Histories dating to 1945 taken from Thomas (1985, 71)

Other documents, captured at the end of the War, revealed that Germany had been ahead in producing an even deadlier generation of chemical weapons, as well as undertaking human experimentation on concentration camp prisoners most notoriously at the ahnenerbe or infirmary at Natzweiler.

Chemical Agent	Production Centre
Mustard	Gendorf Ammendorf
Arsenicals	Strassfurth Hesselhorst Leese
Adamsite	Urdingen
Phosgene	Ludwigshafen Urdingen Wolfen
CN	Hahnenberg Seelze
Tabun	Munster-Lager Dyhernfurth

Table 9 showing German CW production centres taken from Thomas (1985, 82)

3.6 Toxic Incidents

There is always some personal risk or danger of injury when dealing with hazardous substances on a daily basis and toxic accidents happened involving both military and civilian personnel.

Military Personnel

Mustard made at Valley was also used in chemical warfare training for military personnel; the Bomb G. 6lb shells manufactured at Valley were used for this purpose (WO2 Rod Scott pers. comm.), and cases of mustard burns were recorded. It was during one such training exercise in 1943 that a Canadian Lieutenant was fatally injured when he was covered in mustard following an incident in which he kicked a shell (Thomas 1985, 80).

However, just handling shells could be hazardous, as an entry in the Operations Record Book for No. 81 MU Barnes Moor for the 11th November 1942 records:

‘1425 hrs. 38 trucks of 65lb bombs from MS Factory Valley arrived. All trucks contained leakers, out of a total of 3,152 bombs 2,600 were leaking or contaminated. All parties worked in full clothing to unload this train’ (TNA AIR 29/1025).

The worst incident involving CW happened on 2nd December 1943 during the invasion of Italy, where the US Forces were anticipating the use of chemical weapons, a stockpile of 100 tons of mustard (methyl-bis (β-chloroethyl) amine) was on board a ship in the harbour at Bari in Southern Italy. This was bombed exposing thousands of civilians and over 600 friendly troops (83 of whom died) to mustard. The fact that the ship had been carrying CW was not widely known, and many who died had in fact been left for a while prior to treatment covered in a mix of oil and mustard before it was realised what they were dealing with.

Manufacturing Accidents

Below are the monthly accident statistics as reported in the History of Factory Activities 1940-1945 (V-P-49) for Valley.

Rhydymwyn					Randle
Year	Month	Processing	Maintenance	Labs	(Process and maintenance)
1940					
1941	July		1	1	
	August	2		4	
	September			2	
	October	4	17	1	
	November	1	1	3	
	December	3			
			Sub-Total	40	
1942	January		1		
	February		1		
	March	2			
	June	1			
	July	1	2		
	November	5	7		
			Sub-Total	20	44
1943	January	1	2		
	February		2		
	April		1		
	June		1		
			Sub-Total		17
1944	February	1			
	April	1			
			Sub-Total	9	4
Totals				69	65

Table 10 Monthly accident statistics

As is evident above, two particular incidents are referred to in the history where a number of casualties occurred. The first in October 1941 happened during the replacement of one stage of a pump connected with the temporary effluent plant. The second incident happened in November 1942 when another pump failed and toxic effluent contaminated one of the head tanks. This choked the water lines causing parts of the apparatus to overheat. In order to keep the pumps running 'certain risks of skin injuries were taken….. [although] none of the eight injuries sustained was very serious' (V-P-49).

The accident reports for Rhydymwyn need to be considered within the context of the period. Health and Safety was definitely an issue on these sites, but this needs to be considered alongside the fact that Britain was at war. Two stories exemplifying the 'Dunkirk Spirit' of the time are reported by Major Toler in his article on 'Poison Gas manufacture in the UK' (1993). Toler became Randle's Resident Section Manager in 1954, and oversaw much of the decommissioning of Britain's CW arsenal. The first incident he reports upon occurred when a shell ignited during filling at Randle, whereupon the girl handling the shell immediately carried it outside (thus ensuring the safety of other personnel) where it was made safe. The second incident he reports involved key staff at Randle laying aside their Personal Protective Equipment (PPE) in order that they could dig faster to free a blockage that had occurred in the main effluent pipe. In short, all knew the dangers that they faced on a daily basis, but thanks to the spirit of the British population it was considered worthwhile taking the risk.

Decommissioning

It was actually during the process of decommissioning that many of the major incidents occurred. During decommissioning of Valley, chemicals were removed by train to Randle where they were burned. A small leak was found following one such shipment, and Peter Woodward, the chemist in charge of the Valley at that time, had to order that a section of track was replaced and the sleepers burnt in order to contain the incident (Toler 1993, 28).

In another major incident in 1955 there was an explosion and fire at Forward Filling Station 4, Lord's Bridge, Cambridgeshire. Corporal John Saunders, a Royal Air Force fireman, was awarded the George Medal as he had stood on the edge of the crater for thirty minutes directing a constant stream of foam at the remains of K-tank. His actions, and those of the site commander (Flight Lieutenant Edward Campbell who was also decorated as a result of the incident) ensured that there were no casualties, civilian or military, arising from the fire (Toler 1993, 30).

3.7 The Early Post-War period

During the later phases of the war British Forces discovered stockpiles of German shells bearing hitherto unknown markings (a white ring, and green and yellow rings). They were charged with an entirely new and (then) undetectable lethal agent Tabun (Sarin) which had been developed by I.G. Farben whilst developing novel pesticides. This turned out to be an early nerve agent that Hitler had been urged by his generals to employ against the advancing Allies, but his personal experience of being gassed during the Great War had evidently dissuaded him from its use. A small manufacturing plant for this new generation of chemical weapons was established at Sutton Oak, and later moved to Nancekuke in Cornwall. Samples were also supplied to Porton Down where effective counter measures and antidotes were developed (Carter 1992, 2000). Some of these shells (approx. 70,000 in total) may have been stored at Rhydymwyn, although the bulk was held at Llandwrog, in the immediate post-War period prior to their disposal.

Between 1945 and 1947 some of the stockpiles of weapons stored at Rhydymwyn and Randle were gradually decommissioned and disposed of in deep waters off the Continental Shelf (Toler 1993, 28). This started the gradual decommissioning of the Valley facility, with filling and assembly areas being redundant by the end of 1948. Plant and equipment was either, re-used elsewhere, scrapped, or buried in the grounds of the factory in toxic burial pits (Pearson 1996, iv).

However, it was not until 1954 that the Government and Ministry of Supply decided that all stockpiles of mustard and other earlier generation poisonous gases should be cleared. Rather than scuttling them at sea, this time a programme of controlled burning was undertaken at Randle (see Toler 1993, 31-33 for a full account of the processes and equipment used during this exercise). Britain finally unilaterally abandoned her offensive chemical weapons capability in the late 1950s.

The Biological Weapons Convention was signed up to by many countries in 1972. However, poison gases are known to have been used in Afghanistan in 1980-82, and against Iran, the Turks and Kurds from 1983 to 1989. 'Yellow Rain' was used in Laos and Cambodia, and 'Agent Orange' in Vietnam, and more recently Sarin has been used by terrorists on the Tokyo underground.

Since 1993 the Chemical Weapons Convention has forbidden both the manufacture and the stockpiling of chemical weapons by the signatory countries. As such, Rhydymwyn remains on the international list and is monitored by the Hague.

From the mid-60s the site was used by various governmental departments, its major function was as a buffer storage depot to supply emergency rations and foodstuffs, and associated facilities such as mobile bakeries and canteens (ibid). In 1994 the site was finally closed, and a programme of demolition was undertaken across the site. This involved the dropping of buildings onto their footprints, and the rubble being mounded over with topsoil. However, several major structures, and many ancilliary buildings, survive across the site.

The site is just one example of a huge building programme that changed the face of Britain forever, and, as with many other purpose built structures, once their original function is removed they are notoriously difficult to convert for reuse. In this instance the problem of function is further compounded by the site's association with chemical warfare; which is undoubetdly a highly emotive subject.

3.8 Good from Evil: The Legacy of Chemical Warfare

The strong chemical industry in the northwest has its origins in the urgent demand for heavy chemicals for gas warfare in WWI. Perhaps more surprisingly, but nonetheless true, is that the Medical Research Council owes its formation to the medical challenges of warfare, including biological chemistry, surgery, psychiatry, infection and preventative medicine issues, especially anti-sera and immunisation techniques.

Cancer Treatments

Following the incident at Bari (mentioned above), investigation of the toxic mechanism indicated a profound inhibition of the marrow and lymphoid system (Alexander, 1947). On this basis patients with malignant lymphomas including Hodgkin's disease were treated in 1943 with mustine, a related nitrogen mustard, at Yale University in the USA. This was found to dramatically reduce the tumour size and thus was initiated the field of cancer chemotherapy (Gilman & Philips, 1946; Goodman et al., 1946). Related compounds, melphalan, cyclophosphamide and chlorambucil are still in use today. Some of these agents are also used in the treatment of certain forms of renal disease

A further breakthrough in cancer treatment, which copied the success of anti-tuberculosis chemotherapy in which drugs were administered simultaneously to prevent the emergence of drug resistance, was the introduction of combination cancer chemotherapy. MOPP (a combination of nitrogen mustard, vincristine, procarbazine and prednisolone) was shown in the 1960s to cure, for the first time in the history of cancer, patients with Hodgkin's and non-Hodgkin's lymphomas. This approach continues to be the basis of modern cancer chemotherapy treatment today, and further studies of mustard gas victims have also been used to increase our understanding, and help to avoid, some of the side effects that chemotherapy has.

Improved Pesticides

Reference has already been made to the development by the Germans of organo-phosphorus nerve gases during WWII and their failure to use them for fear of retaliation-in-kind. In the post war period the British continued research into these compounds, mainly to develop detection and protection measures. However, all stocks were destroyed in the late 1950s following the decision to abandon chemical and biological weapons in 1956.

The initial research that led to the discovery of Sarin was part of an attempt to make novel, highly selective pesticides. This work has continued and several compounds, which are, in fact, organo-phosphorus derivatives, are in widespread use today. These include the insecticides Parathion, Dichlorus and Malathion. The latter also has a medical purpose, and is recommended for the treatment of human scabies, head lice and crab lice by current British National Formulary. More recent developments include the widely used, highly effective, herbicide Glyphosate (Round Up). These applications attest to the safety of what are (in effect) non-toxic nerve gas analogues. Other derivatives currently in medical use include bisphosphonates, e.g. Alendronic acid and Disodium Etidronate, highly effective in the treatment of osteoporosis and allied bone diseases including malignancies and Donepezil used in the treatment of Alzheimer's disease (Emsley, 2000).

Peace

A telegram bearing the immortal words 'Babies satisfactorily born' was sent to President Truman informing him that the Trinity Test of the first atomic bomb at Alamogordo in New Mexico on 16th July 1945 had been successful. The Japanese were offered the opportunity of surrender but their military rulers rejected this. After repeated warnings atomic bombs were dropped on Hiroshima and Nagasaki and surrender followed swiftly on September 2nd. It was estimated that the bomb saved a million American and half a million British lives that would have been lost if victory had been prosecuted by conventional means (Churchill 1954). Records in The National Archives document the contribution of Valley to the development of atomic energy for both military and peaceful ends (TNA, AB16/266).

The Maud Committee Report in July 1941 concluded that a bomb could be ready by the end of 1943. In appendices the contributions of Professor Chadwick and colleagues of Liverpool University on the fission cross-section studies predicting the amount of uranium necessary are described. There is also a discussion of the possible methods for separating the active U235 from the large excess of inactive U238 in uranium ore. The use of gas centrifuges, the current method employed, was initially rejected as the necessary technology had not yet been developed. Much more promising was gaseous diffusion and a full account of the theoretical and practical basis for the separation equipment including a rough sketch was provided by Dr. (later Professor) F. Simon of the Clarendon Laboratory, Oxford. These vital early experiments were conducted at Valley (Gowing, 1964). Also recognised by the Maud Committee were the peaceful uses of atomic energy and the British Team carried out the relevant experiments in parallel with the Americans who concentrated on their military potential. As well as the non-polluting production of energy, the results of these studies have enhanced the use of radioisotopes in scientific research, medical diagnosis and treatment, particularly of cancer as well as a variety of technological innovations.

The important contributions of Franz (later Sir Francis) Simon FRS (1893-1956) to the work at Rhydymwyn and the British nuclear energy programme have already been mentioned, and it is perhaps worthwhile recalling that he was a Jewish exile from Germany. Professor Lindemann (Lord Cherwell) recruited him on a 'shopping trip' for the Clarendon Laboratory with the help of an I.C.I. grant of £800 in July 1933. He moved to the United States in 1943 to work in Los Alamos on the Manhattan Project, returning to Oxford to continue research on low temperature physics. He lost relatives in the Holocaust. At least 1,500 scientific refugees moved to Britain to escape Nazi persecution, including Frisch, Fuchs and Peierls, 20 of whom went on to win Nobel Prizes (Medawar & Pyke, 2000).

Safety and Entertainment

Various incendiary devices were developed during WWI and were extensively used in later conflicts. However, their more peaceful by-products should not be ignored. These include distress flares and rockets in regular use today, as well as ornamental fireworks, particularly the current professional displays.

CHAPTER 4 CHEMICAL PROCESSES

Peter Bone

4.1 Introduction

M.S. Valley Site was a chemical weapons manufacturing, charging, assembly and storage site located at Rhydymwyn approximately four miles from Mold in North Wales. The site was built in 1940, became operational in January 1942, and continued to make mustard gases until April 1945. The process buildings were decommissioned in 1948. One building (Bldg 45/P6), which had been originally designed to manufacture Pyro mustard, was used for early gaseous diffusion experiments as part of Britain’s atomic weapons programme codenamed Tube Alloys.

This report has been prepared as part of a Historic Features Management Plan prepared by Birmingham Archaeology and covers the following aspects of the chemical plant and processes on the site;

- Overview of the Production Facilities
- The Runcol mustard plants
- The Pyro mustard plants
- Utilities and ancillary services

The report includes an appendix giving a list of the chemicals used on the site. The use of Building 45 as part of the atomic weapons programme is covered in a separate section.

Overview of the Production Facilities

The site is located in the Alyn valley at a height of about 400ft O.D., it has an area of approx 90 acres, is approximately 1⅛ long, 1200ft wide at the north end and 500ft wide at the south end. Five main activities were carried out on the site;

- Production of chemicals at the north end of the site
- Storage in underground chambers under the western hillside
- Charging in buildings K.4 and K.5 outside the underground chambers in the centre of the site
- Assembly of munitions in approximately 45 buildings connected by cleanways (walkways) at the south end of the site
- Nuclear research in building 45 on the western side of the main roadway at the north end of the site.

The design capacity of the plant was 240 tons/week of Pyro or 216 tons/week of Pyro ‘M’ plus 100 tons/week of Runcol. At any one time there was the capacity to have about 280 tons of toxic material in-process between chemical production, charging and munitions assembly. There was underground bulk storage capacity for about 1,500 tons of toxic material, which is about 4-5 weeks production at full capacity. These figures are theoretical as the Pyro plants never went into production and were only used for upgrading material made elsewhere.

Plant	Building	Purpose	Design Output
P.4	Bldg 59	Pyro and Pyro 'M' production (Never put into production)	80 tons/week Pyro Or 72 tons/week Pyro 'M'
P.5	Bldg 50	Pyro and Pyro 'M' production (Only used for conversion of Pyro to Pyro 'M' and upgrading by heat treatment)	80 tons/week Pyro Or 72 tons/week Pyro 'M'
P.6	Bldg 45	Originally design for Pyro but plant was never installed. Used for gaseous diffusion experiments to separate U235 from U238 as part of "Tube Alloys" Britain's atomic weapons programme	
R.3	Bldg 65	Production of Runcol	50 tons/week Runcol
R.4	Bldg 35	Production of Runcol	50 tons/week Runcol

Table 11 Weekly outputs for each building

Each plant was completely independent with its own stocks of raw and service materials except that utilities (steam, water, electricity) were drawn from central supplies. There were no individual plants for the production of intermediates. Each Pyro plant had its own ethylene manufacturing plant and each Runcol plant had its own acid concentration plant. The plant was operated by I.C.I. General Chemical Division on behalf of the Ministry of Supply. I.C.I. also operated similar chemical weapons facilities in the North West at Widnes (Randle), Preston (Springfields). Intermediates were manufactured in Widnes (Randle), Northwich (Wade) and Runcorn (Rocksavage). The numbering of the plants follows an I.C.I. sequence plants R.1 and R.2, P1, P2, P3 were located at Randle and predate the Valley plants.

4.2 Runcol Mustard Plants

Chemistry

In general, complex chemical names were not used on the plant or in process descriptions, intermediates and toxic products were known by code names; sometimes there was more than one name for the same material. Runcol is the I.C.I. name for H.T. Mustard. It consists of 60% bb'dichlorodiethyl sulphide, $(CH_2ClCH_2)_2S$ (known as H) and 40% di (b'chloroethylthio) diethyl ether $(CH_2ClCH_2(CH_2CH_2)0)_2S$ (known as T). Both these compounds are produced by the reaction between thiodiglycol (known as Syrup) and hydrogen chloride. When Syrup is heated with excess Hydrochloric Acid (HCl) the product is almost exclusively H. T is produced when gaseous Hydrogen Chloride (HCl) is passed into excess Syrup. The principal condition governing the ratio of H to T in the final product is the relative concentrations of Hydrogen Chloride and Thiodiglycol in the liquid phase. HCl reacts with the T already formed and converts it to H.

Process Description

The process and plant description for the Runcol plants have been developed from two I.C.I. General Chemicals group reports declassified in 1996.

Report on H.M. Factory Valley General Description (V/SPS/7)
Report on 50 Ton/Week Runcol Plant Flowsheet and Plant Item Summary (V/SPS/11)
The manufacture of Runcol had five separate operations,

Generation of gaseous HCl
Reaction of HCl with Syrup
Separation of the Runcol from the aqueous acid layer
Drying of the Runcol
Effluent treatment

Gaseous HCl was generated by the action of 95% Sulphuric Acid on aqueous HCl in a continuous process. The two acids flowed from header tanks and were mixed in a gas generator. The HCl gas evolved was stored under pressure in a balance tank. The spent sulphuric acid at about 74%, which contained about 0.5% HCl passed to two hot air blowing towers in series to reduce the HCl content and then to a sulphuric acid concentration plant to be concentrated back to 95% for re-use.

The reaction between HCl and Syrup was a batch process. It was carried out on a relatively small scale using about 250 litres of Syrup for each batch. The Syrup was preheated and then run into the reaction vessel with hydrochloric acid. Gaseous hydrogen chloride generated in step (a) was then bubbled through and the reaction controlled to produce the correct H to T ratio. At the end of the reaction the mixture was air blown to remove excess Hydrogen Chloride and then water was added before the batch was transferred to a settler.

Runcol is almost insoluble in water. The reaction mixture settled into a lower Runcol layer and an upper toxic acid layer, which contain unreacted materials and water-soluble impurities. The Runcol was separated to a Runcol receiver under vacuum using a dip pipe and sight glass. The upper aqueous layer was transferred to a toxic acid receiver. This layer was diluted with water and allowed to settle again before being transferred to second toxic acid receiver and then to an effluent pit for final treatment and dumping.

Three batches from the reactor were collected in the Runcol receiver and any further aqueous layer was run off back to the settler. The Runcol was then transferred to the drying still. The drying still operated under vacuum and was heated by a steam jacket. The residual water and HCl was driven off the Runcol, condensed in a lead coil condenser and transferred to the second toxic acid receiver. The dried Runcol is cooled and then transferred by vacuum to buffer storage outside the building.

The toxic acid collected in the second toxic acid receiver contained about 10% HCl and was discharged to an effluent treatment pit together with the mixed process effluent from the rest of the plant. The vast majority of the effluent (99%+) was water from scrubbing and washing systems. Sodium Hypochlorite was added to the effluent to reduce odour. The effluent pit could be used to hydrolyse any Runcol and could if necessary be filled with lump limestone to neutralise any acid.

Plant Buildings and Layout

There were two Runcol plants on the Rhydymwyn site R3 (Bldg 65) and R4 (Bldg 35). As far as is known the process engineering and plant layout in the two building was identical. The only difference being that R4 was of 7inch reinforced concrete construction and R3 was of R.C. frame with 9inch brick infill. R4 has been completely demolished. R3 has been stripped of all plant and fittings but the shell of the building and some external ancillary structures remain. In both cases the acid concentration plant buildings have been demolished. Internal and external inspection of R3 shows that the plant arrangement would have closely conformed to Drg No JRL 26858 (Armstrong & Hudson 1940). There is a detail inventory of the plant drawn up by I.C.I. prior to decommissioning and stripping of the plant in 1948.

Process Building

Each Runcol plant consisted of a toxic process building approximately 99 ft long, 27ft wide and 27ft high. The stock tanks were located outside the building and acid concentration was carried out in a separate building as described later. The process building was divided into two main sections with the HCl generator section 32ft 9inches long separated from the toxic section 71ft 8inches long by a 9inch brick (R3) or 7 inch R.C. partition wall. All the toxic plant was housed in four island cubicles built end to end in this section of the building. Three of the cubicles were used for reactions and were identical; two were in use at any one time with the third on standby. They measured 11ft 4inches by 12ft 6 inches by 14ft high and were of reinforced concrete construction (or possibly 9inch brick in the case of R3) with triplex glazed windows and removable roofs. They each contained a reaction vessel, reflux condenser and separator and associated items of plant. The fourth cubicle furthest away from the partition with the generating section was equipped with the toxic receivers and drying stills. Two sets of equipment were provided one working, one on standby. This cubicle was 17ft by 12ft 6inches by 14ft high. There was a raised control platform running right round the outside of the cubicles to allow operation of the plant via remote valves or by allowing hand access to the cubicles through small sliding windows. The arrangement of plant in the cubicles is shown on I.C.I. drawing JRL 26858 in report V/SPS/11.

Ventilation

A ventilation trench 3ft wide and between 2ft and 3ft deep lined with white tile ran the whole length of the building and connected to the effluent pit outside the building. The inlet of the air washing plant was connected to the cover of this effluent pit and a 42 inch 23,000 cfm exhaust fan on the air washer drew air from all sections of the plant through floor gratings into the ventilation trench. The air washers were located on concrete foundations about 32ft from the north end of the building and exhausted through a self-supporting steel chimney 5ft in diameter and 60ft high. Air was blown into the building by two fans, one of 15,000 cubic feet/min (cfm) and one of 8,000 cfm high in the end walls of the building; the air was heated if required by steam heaters.

Ancillary Plant

Ancillary plant such as vacuum pumps and air compressors were located in lean-to buildings along the wall outside the building. Pumps were housed on staging measuring 22ft by 7ft 6inches by 15ft 9 inches high outside the building and covered by sheeted structures. Four hydrochloric acid tanks, one sulphuric acid tank, two spent acid tanks and two Syrup stock tanks were sited beyond the pumps. The Runcol cooler was mounted outside in its own 9-inch brick building.. Buffer pots were mounted in two pits approximately 11ft in diameter and 11ft 9inches deep near the effluent pit about 45ft from the building.
Sulphuric Acid Concentration

The sulphuric acid concentration plant was housed in a separate building 74ft by 46ft 10 inches by 28 ft high with a Belfast roof and fan annex 27ft 8 inches by 14 ft by 13ft 6 inches high. The buildings housed two concentration units with a capacity of 15 tons/day of 95% sulphuric acid from 68% acid. The concentration process relied on the counter-current flow of dilute acid against a furnace gas at an inlet temperature of 600oC.

The unit is described as an Evans-Bowden type engineered by Simon Carves of Manchester; it would have been similar to the Kessler Concentrator shown below. The air was heated in a coke fired producer which was of firebrick lined brick construction 12ft 6inches by 8ft 9inches by 12ft high. The concentrators were built in acid resisting brick (not the Volvic Lava shown in the diagram) and were connected to the producer by a firebrick flue. The Saturex Chamber was 16ft 6inches by 6ft 10inches by 3ft high and was built into a steel framed lead trough carried on four blue brick piers 4ft 2 inches high. The concentrator tower was 6ft 4inches square and 10ft 3inches high. The outlet gas went to a scrubber, which was 25ft by 20ft by 7ft deep it was timber framed and boarded and completely lead lined. The walls and floor were additionally tile lined and it was built on a separate concrete raft 27ft 6inches by 24ft carried on three 18-inch high sleeper walls. The air was drawn through the scrubber by a 21inch 30 h.p. Kestner lead lined fan.

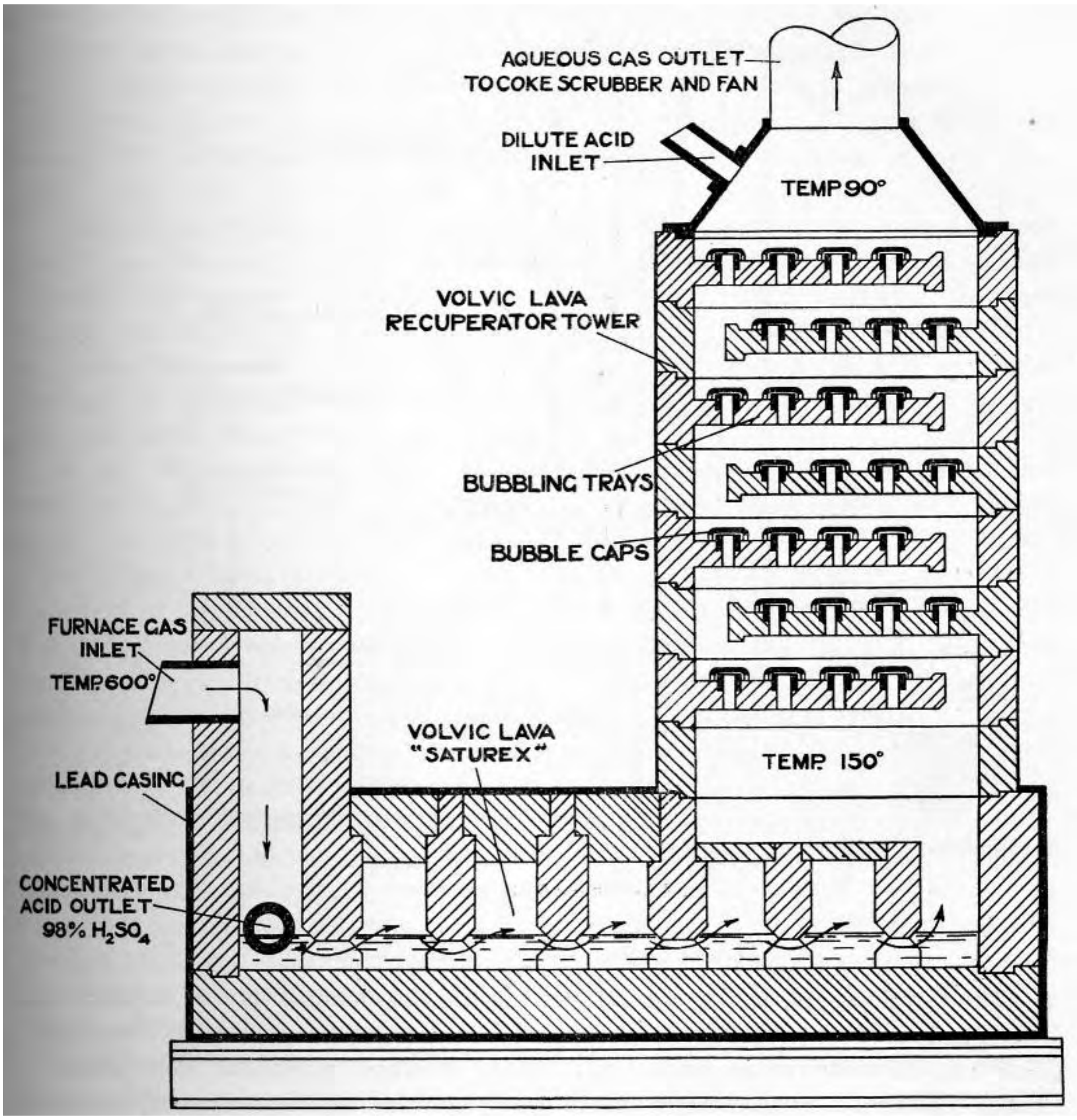


Figure 10 Kessler Concentrator (Morgan & Pratt 1938)

4.3 Pyro Mustard Plants

Rhydymwyn was originally designed to have three Pyro mustard plants in buildings P4 (Bldg 59), P5 (Bldg 50) and P6 (Bldg 45). The design was similar to Pyro plants at Randle and Springfields. Plant was installed in P4 and P5 and maintained in operational condition but it did not go into production. The plant was fully commissioned (i.e. checked and brought to full operational status without using toxic materials) and held on standby, it was even modified and updated as a result of process developments at Randle and Springfields and in the laboratories at Rhydymwyn. No toxic materials were handled in P4. P5 did not manufacture Pyro but the heat treatment plant in P5 was used to upgrade Pyro manufactured elsewhere and therefore became highly contaminated.

Work on the erection of P6 (Bldg 45) Pyro plant was stopped in April 1941. The building had been completed and the alcohol and monochlorobenzene storage tanks, the ethylene gasholders, electrical transformers and switchgear had been installed. The building was taken over by the "Tube Alloys" project for nuclear research; it is covered in a separate report.

Chemistry

Pyro is the I.C.I. name for a process to produce Mustard (bb'dichlorodiethyl sulphide) by the reaction of Ethylene with Sulphur Dichloride (SCl2), referred to by the code S.20, dissolved in Carbon Tetrachloride at 35oC (Pearson 1996). This is not the Levinstein process that uses Sulphur Chloride (S2Cl2) but is a close relation to it. The reactions between ethylene and the sulphur chlorides are complex (Conant et al. 1920) and involve a variety of unstable intermediates and continuing side reactions, they were not fully understood until after the war (Macy et al. 1947). The reaction is not particularly efficient and a number of by-products are produced. The resultant mixture is known as 'HS', it is impure and corrosive and was considered too crude and unstable to be of military use without further refining. 'HS' was vacuum distilled to strip the Carbon Tetrachloride to less than 1% and 8-12% of Monochlorobenzene (MCB) was added to give a product called "HM" or Pyro "M". Benzene could be used in place of MCB to give "HB" (Pearson 1996).

Pyro Production - Process Description

The process and plant description for the Pyro plants have been developed from I.C.I. General Chemicals group Report on H.M. Factory Valley General Description (V/SPS/7), the history of the plant written by Mr Thomas, the plant manager, in 1945 and the plant inventories taken during decommissioning. It is understood that there was a report detailing the Pyro plant flowsheets and plant item description (V/SPS/9) but this has not been found in archives. The description is therefore more tentative than the Runcol process.

The Pyro production plants would have produced the impure material "HS", the plants consisted of four sections;

- Ethylene Production
- Mixing and Recovery
- Reaction between Ethylene and Sulphur Dichloride
- Scrubbing and Regeneration

Ethylene is produced by the catalytic dehydration of ethanol. The catalyst is a strong acid (80% Phosphoric Acid) absorbed on a silica substrate. The proprietary materials Sorbsil and Gasil, which were produced at that time by Joseph Crosfield in Warrington, are both mentioned. The ethanol is vapourised, superheated, and passed through the catalyst bed in a furnace where the dehydration reaction takes place; the Ethylene is cooled before passing to storage and then to the reaction plant. The catalyst progressively deteriorates by the absorption of water and has to be regenerated by heating in a furnace and treated with Phosphoric Acid in a saturator to reactivate it for reuse.

In the mixing and recovery section sulphur dichloride was dissolved in carbon tetrachloride. The process must have been exothermic as brine cooling was required to remove heat. After the reaction to form Pyro the carbon tetrachloride was recovered and recycled.

Pyro is made by the reaction of Ethylene and Sulphur Dichloride. Ethylene was drawn from gasholders outside the plant and blown through the Carbon Tetrachloride/Sulphur Dichloride mixture, the Pyro and Carbon Tetrachloride distilled over and was condensed. The plant was equipped with an ethylene circulator, which suggests that excess gas was passed through and circulated round the reaction vessel. The Pyro and Carbon Tetrachloride could then be separated and further Pyro recovered by fractionation.

There would have been a number of gaseous and vapour effluents from the plant including carbon tetrachloride vapour, Pyro and ethylene. The plant was equipped with barometric scrubbers equipped with calcium chloride towers to remove Pyro under vacuum and calcium chloride towers associated with the ethylene washers. There were also ten silica gel towers and a silica gel regeneration combustion chamber burning alcohol.

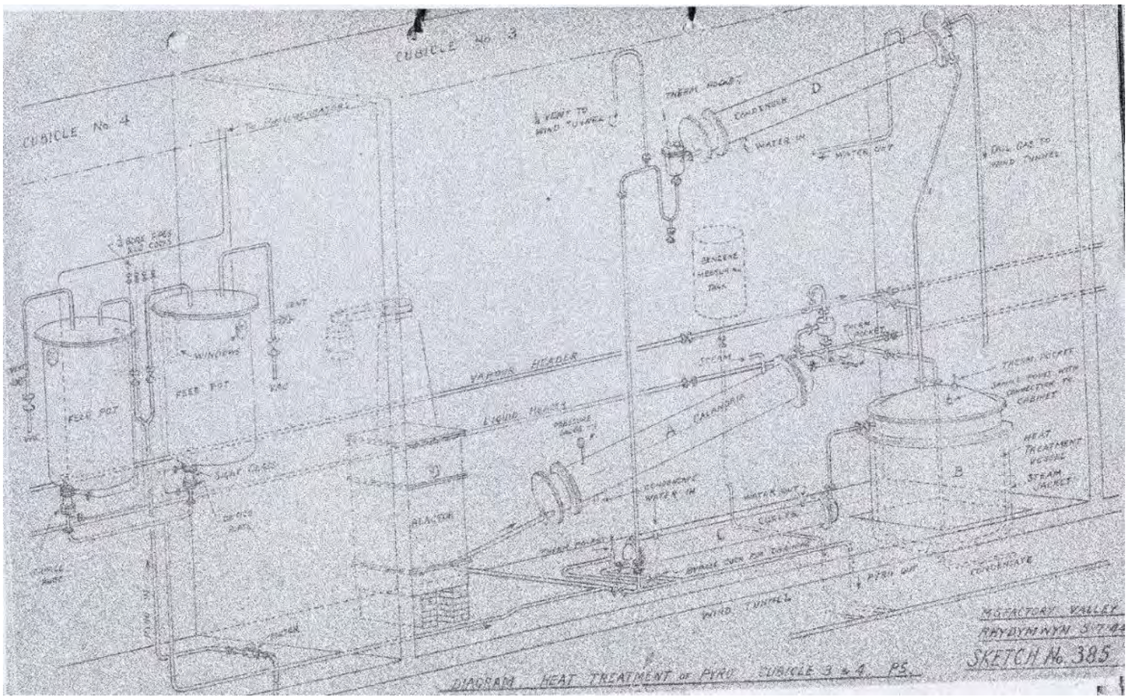
Pyro Conversion – Process Description

The material produced by the ethylene/sulphur dichloride process was considered too unstable and impure for military use. The reaction to form Pyro was inefficient and a number of corrosive and unwanted by-products were produced. When originally built and commissioned in 1941 the P4 and P5 Pyro plant had been designed to convert this Pyro (HS) to Pyro 'M' (HM). This involved stripping the carbon tetrachloride reaction solvent by vacuum distillation to a level of less than 1% and then mixing the stripped Pyro with 8-12% of Monochlorobenzene (MCB). It was a physical process no further chemical reaction was involved. In 1942 the process was modified to use Benzene instead of MCB and stirred reactors were installed in the conversion cubicles. The resultant material was known as HB. There is also some indication, as described later, that a process was developed so that HB could be made directly, this material was known as HBD. Although the crude Pyro was never made at Rhydymwyn the conversion process was carried out on material made at Randle and Springfields and the product was stored in the underground chambers on the site.

Pyro Heat Treatment – Process Development and Description

It was found that in long-term storage even HBD made by the direct process caused problems. Unstable impurities slowly decomposed to produce hydrochloric acid. The acid attacked the mild steel storage containers and the gas produced pressurised the tanks. The C.I.D (Chemical Inspectorate) laboratory at Rhydymwyn found that if the material was heat treated at 140oC for 3 hours the impurity causing the instability was destroyed. A laboratory test was developed that graded the Pyro by stability based on acidity from Grade I to Grade III. Material in Grade I was stable; material in Grade II was suitable for heat treatment and material in Grade III had to be blended to an acidity of less than 4% before treatment. Only Grade I material with an acidity of less that 0.3% was considered suitable for thin cased weapons such as the 65lb bomb. The process was tested at a pilot plant scale at Sutton Oak and used on the production plants at Randle and Springfields.

A decision was taken in 1944 to heat treat existing stocks from all the other factories at Rhydymwyn. This was about 1400 tons of material at Grade II and Grade III. This required further modifications to the plant in cubicles 3 and 4 of P5 and direct piping from these units to the underground storage. Grade II and Grade III HBD was brought to the plant by road wagons (Thomas 1944).



The process is shown on the isometric sketch above. Material was taken from storage and held in three 500 gall underground tanks outside the plant originally intended as HS feed tanks. It was transferred by vacuum to a header tanks and then passed by gravity through the process. It flowed through a Monel tubed steam heated Calandria and then via a dip pipe into an enamelled lined heat treatment vessel. This vessel was heated by a pressurised steam jacket to 125oC. The process was continuous and the vessel gave a residence time of about 2¾ hours. The run off went though a cooler from where it went to 1000 gall buried tanks mounted on weighing machines outside the building. Hydrochloric acid and benzene vapour were condensed in a water-cooled double pass condenser.

The Plant was started on August 21st 1944 and was run until 13th November 1944, process operators had been trained at Randle and no major difficulties were encountered (Thomas 1944). When the plant was running continuously it had had an output of 90 tons per week a maximum of about 1100 tons of material would have been processed in the short time the plant was operational.

Other Process Modifications

In his History of the Site, Thomas makes reference to other plant modifications. Construction of S.20 (Sulphur Dichloride) distillation units in P4 and P5 were started in 1942. A detail list of the plant involved is contained in the inventories. Construction could not have had very high priority as they were only being completed in summer 1944 when Thomas states,

> In the spring of 1944 Construction department began to convert the four production cubicles for the manufacture of Grade I HBD by the direct process. The general layout of the plant in the cubicles which it was then proposed to adopt as standard for all factories is shown on Drawings Nos. JPY42374B and JPY 42384B. By the summer the S.20 distillation unit was practically complete, a number of the men had been trained at M.S.F. Randle and the plant could be regarded as ready to commence production of Grade I HBD at the rate of approximately 100 tons/week
>
> (Thomas 1944).

Little is currently known about the direct process and the drawings referred to have not been found.

Plant Buildings and Layout

Each Pyro plant was housed in a rectangular building 208ft 9 inches by 155ft 9inches by 23ft high to the underside of the roof beams with a reinforced concrete frame and 9” brick infill and an arched concrete roof. The building is described in the 1948 inventory as divided by brick walls into four internal sections and two external units corresponding generally to the processes described above.

- Furness House for (Ethylene production)
- Process and Scrubber Room
- Engine Room
- Mixing and Recovery section
- Ventilation, air washing, filtration and discharge plant (outside the building).
- Buffer storage and effluent pits (outside the building)

Furness House

The Furness House can be considered in three parts.

- The Ethylene production unit which consisted of an alcohol vaporiser, preheater, ethylene furnace, ethylene cooler and their associated minor plant.
- The catalyst circuit consisting of catalyst drying furnaces and catalyst saturator.
- The stock tanks and gasholders buried outside the building.

There were seven ethylene production units in both P4 and P5. Alcohol was drawn from one of two 70 ton (12,000 gall) mild steel tanks, buried in 18ft 6 inch diameter by 15ft deep pits outside the building to a steam heated (alcohol boils at 78oC) vaporiser. The alcohol vaporiser was a mild steel vessel 12inches in diameter and 7ft high mounted on a steel frame, it fed a fuel oil fired alcohol preheater of firebrick 18ft 10inches by 3ft 10inches by 6ft high. The alcohol vapour passed through a two inch steel coil to the ethylene reaction furnace. These furnaces were of firebrick construction 18ft 9 inches by 11ft 6inches by 8ft high, with Mild Steel tubes, fuel oil burners and steel flues and chimney. The chimney was 2ft diameter and 32ft 9inches high. The ethylene passed through a cooler, condenser and water separator to one of two 6,000 cu ft mild steel single lift gasholders in R.C. pits 71ft 6 inches by 31ft 6 inches by 2ft 6inches.

The catalyst for the reaction to produce Ethylene was Phosphoric Acid carried on a silica substrate. Water is produced in the reaction to form Ethylene the catalyst and the substrate would gradually deteriorate and would have to be regenerated. This was done in one of two firebrick furnaces 14ft 3inches by 5ft 9inches by 6 ft high with steel flues and chimneys. The substrate then had to be saturated with the acid; this was done in a rotating cast iron drum 3ft 9inches in diameter and 5ft long.

Process Section

The toxic process section in each building consisted of seven cubicles 29ft by 8ft 11inches by 17 ft high. There were five reaction cubicles and two conversion cubicles. As far as is known none of the reaction cubicles were ever used for production. The stripping cubicles in P5 were used for conversation of Pyro manufactured elsewhere to Pyro ‘M’.
Each reaction cubicle was equipped with

- Cast iron reactor in 3 section 2ft 6 inches by 3ft 1inch by 4ft 6 inches deep with a gear driven 5 h.p. agitator.

- Solvent Pyro/ethylene separator
- Solvent Pyro receiver
- Calandria (Steam heated tubed heat exchanger) 12 inches diameter by 9ft 7 inches long with Monel tubes
- Pyro/Carbon Tetrachloride condensers 12 diameter by 9ft 7 inches long with Monel tubes
- Pyro Treatment Vessel (fractionator) Cast Iron, glass enamel lined, with a steam jacket, 4ft diameter and 5 ft 5 inches long.
- Product cooler mild steel shell with Monel tubes, 9inches diameter and 8ft 10inches long.
- Pyro receiver cast iron 2 ft 9 inches in diameter and 4ft 3 inches long.

The conversion cubicles were equipped with

- Calandria 12 inches diameter by 9ft 7 inches long with Monel tubes
- Stripped Pyro/Carbon tetrachloride vapour separator cast iron 1ft 4inches diameter by 1ft 9 inches high.
- Two stripped Pyro receivers cast iron 140 gall capacity
- Pyro M blender cast iron 2ft 8 inches diameter and 4ft 3 inches deep.
- Fractionating column, bubble cap type in 6 flanged sections, cast iron 3ft 3 inches diameter by 6fy 1 inch high.
- Carbon tetrachloride condenser Mild steel shell with Monel tubes, 18-inch diameter and 7 ft 1 inch long.
- Two carbon tetrachloride receivers cast iron 60-gall capacity.
- There was a Monochlorobenzene (M.C.B) measuring vessel located outside the cubicle. This was 25-gall capacity with an agitator.

The only access to the reaction and conversion cubicles was through external large steel doors, which would have been locked shut except during maintenance shut-downs, if the plant had gone into operation.

All the valves controlling the plant inside the reaction and conversion cubicles were brought through the cubicle walls into the reaction control room. There were mild steel sampling cupboards with Triplex glass windows, 16inches by 16inches by 2ft in both the reaction and stripping cubicles. A trench beneath the floor of the control room carried away the pipes to and from the reaction cubicles. General instruments and controllers were also mounted in this room and there were emergency washing facilities.

Scrubber Section

The scrubbers were mounted in the same section of the building as the reaction control room. The following plant was installed in this section.

- Carbon tetrachloride separator and catchpot, cast iron
- Ethylene cooler, mild steel welded construction 3ft diameter and 3ft 6 inches deep with a lead coil.
- Two ethylene wash towers, cast iron 2ft 10 inches diameter by 12ft high
- Four calcium chloride drying towers (Two working two standby/regenerating), cast iron, 2ft 10 inches diameter by 9ft high
- Sulphur Dichloride cooler 3ft diameter and 5ft 2 inches deep with a lead coil.
- Ten silica (Sorbsil and/or Gasil) drying towers (five working five standby/regenerating), mild steel, 2 ft diameter by 5ft 7 inches high
- Barometric scrubbers and calcium chloride towers on the three vacuum systems, some of this equipment was made of “Keebush” a type of chemically resistant thermosetting plastic.

The barometric scrubbers are connected to the high vacuum (28½"Hg.) system and the plant vacuum (15"Hg.). In order to work correctly they need to be fitted at a minimum height, allowing for installation and maintenance, of 34ft for 28½"Hg system and 18ft for the 15"Hg system. They must have been mounted in the raised (referred to in the inventory as “penthouse”) section of the building. A 48-inch extraction fan is also mounted in this raised section and it discharges to a 4ft 2inch stack 32 ft high.

Engine Room

The Engine Room contains all the rotating plant for refrigeration, gas compression and circulation. The following items of plant were installed in this section.

- Main brine tank 24ft by 18ft by 6ft deep incorporating a separate smaller balance tank.
- Four 3 cylinder ammonia refrigeration units (2 working, 2 standby) with 60 hp. motors
- Three low pressure brine pumps Gwyne Type R with a capacity of 18,000 gall per hour at 12 lbs/in2 (2 working, 1 standby)
- Two Ethylene compressors for transfer from gasholders - 35 hp. Hick Hargreaves type R.C.11.A with aftercoolers and oil separators, 615 cfm at 10 lbs/in2 (1 working, 1 standby)
- Two air compressors – 45 hp. Hick Hargreaves type RC.9 with oil separators 527 cfm 30 lbs/in2 (1 working, 1 standby)
- Two air blowers for Sorbsil/Gasil regeneration – 28 hp Hick Hargreaves type R.C.11.A with oil separators, 546 cfm5 lbs/in2 (1 working, 1 standby)
- Two low vacuum pumps 15"Hg – 28 hp. Hick Hargreaves type RV.11.S 590 cfm (1 working, 1 standby)
- Three high vacuum pumps 28½ "Hg 20 hp. Hick Hargreaves type RV.9 180 cfm (2 working, 1 standby)
- Minor plant items such as condensers and receivers.

Mixing and recovery

The mixing and recovery section prepared the reaction materials. These were considered much less hazardous than the toxic products and the plant was not contained in sealed cubicles.

- Two S.20 (Sulphur Chlorides) stock tanks, Mild steel, lead lined with 3inch thick cork insulation, 11ft 6 inch diameter and 7ft 9inches high.
- Two mixing vessels, mild steel, lead lined fitted with 2hp agitator and Monel float level control.
- Measuring vessel, mild steel lead lined.
- Earthenware fume tower, 9inch diameter and 11ft high.
- Carbon tetrachloride recovery plant consisting of blow-egg, recovery still, condenser and brine cooled water separator, decanting vessel, receiver, two carbon tetrachloride pumps (1 working 1 standby), toxic carbon tetrachloride and recovered tetrachloride stock tanks.
- Wash towers and calcium chloride drying towers

Ventilation

There were a series of forced ventilation systems supplying different parts of the plant all of which were supplied by the Andrew Machine construction Company Limited.

The main unit, which extracted air from the toxic process section, consisted of two 172,000 cfm fans drawing air from the building through an air washing system and discharging to an 8ft square reinforced concrete chimney 80ft high. The air washer, circulation pumps, water filters and ancillary plant were mounted on concrete foundations at the North end of the buildings and connected by underground brick and concrete ducts to ventilation trenches in the building.

There was also a separate 48 inch extract fan in the Pent House section of Scrubber unit that was connected to a 4ft 2 inch diameter 32ft high stack.

In the recovery section there was a separate 10,000 cfm extract fan with a 3ft diameter 40ft high stack connected by mild steel ducting to ventilation trenches in the floor.

Air was fed into the building through 6 wall mounted, steam heated cowled and louvered fan units. Four were of 36,000 cfm and 2 of 24,000. The Ethylene section had similar units without the steam batteries, which were extracting air; air was fed to the ethylene section by 4ft square ducting with drops to floor level.

Storage

Buffer storage for Pyro and Pyro “M” before transfer to the underground storage and effluent treatment pits were located outside the building as follows.

- Two 500-gall pots to hold Pyro before conversion to Pyro “M”, these pots were of cast iron 5ft diameter and 4ft 6inchs deep. They were mounted on Berry and Warmington 4-ton capacity platform type, dial weigh machines. The pots and weighing machines were in pits 11ft in diameter 10ft 6 inches deep with 2ft thick R.C. base, brick and concrete walls and a R.C. cover.
- Two 1000 gall pots to receive final product Pyro ”M” before transfer to underground storage these pots were of cast iron 6ft diameter and 6ft deep. They were mounted on Berry and Warmington 5-ton capacity platform type, dial-weighing machines. The pots and weighing machines were in pits 11ft in diameter 12ft deep with 2ft thick R.C. base, brick and concrete walls and a R.C. cover.
- Two 1000-gall pots to receive all plant effluent for treatment with sodium hypochlorite before discharge to the toxic drain.

Materials only remained in buffer storage for as long as it took to fill, sample for analysis and transfer back to the reaction units or storage.

The S.20 Distillation Plant

The S.20 distillation plant was built in the mixing and recovery section. The steel structure for the plant was 29ft 3inches by 21ft 5inches and 25ft 11inches high, it had a R.C. intermediate floor, brick panel walls and steel staircases. There was a separate 7,700 cfm extract fan with mild steel ducting discharging to a 2ft 2-inch diameter 50ft high stack.

The purpose of the plant has not been confirmed but from the plant description it is most likely to be the production of a pure form of sulphur dichloride. Sulphur Monochloride (S2Cl2) and Sulphur Dichloride (SCl2) are both produced by the action of dry chlorine on elemental sulphur. Sulphur monochloride is in equilibrium with the dichloride according to the equation (Conant et al. 1920).

S2Cl2 ↔ S + SCl2

The presence of the sulphur is responsible for the undesirable by-products and residues, which affect the stability of Pyro and Pyro ‘M’. The inventory includes water jacketed, mild steel chlorinator columns 9inches diameter and 9ft high and two brass fractionator sectional columns, which would support the conclusion that hypothesis that sulphur dichloride was being purified by chlorination and distillation for use in the direct process to HBD.

Utilities and Ancillary services

In order to service the chemical production facility a number of utility and ancillary services were required. These can be divided into three categories;

- Process services (Boilers, pump houses, substations)
- Support and Administrative (Offices, laboratories, workshops)

- Health and Welfare (Fire, ambulance, laundry, canteens)

Only the process services are dealt with here since they relate directly to the production facilities.

Boiler Houses

There were two boiler houses on the site each containing four John Thompson Super Economic Double Return Tube Boilers, they were 11ft 6 inches diameter and 22ft 6inches long from tube plate to the back of the combustion chamber. The nominal output was 45,000 lbs/hour of steam at 60 lbs/in2. The boilers were fired on coal and were fitted with 'Triumph' mechanical stokers and forced draught fans. The boilers were normally feed with Birkenhead water, without pre-treatment, at mains pressure. If this supply was lost they could be fed with mines water via a booster pump and an Endicott water treatment unit.

All boilers fed into a common overhead steam main. Three boilers were normally required to supply process loads; seven boilers were required in severe winter conditions to heat ventilation air to process buildings, underground storage and offices.

Substations

There were two main substations each served by a 33KV overhead line from the North Wales Power Company's substation at Hawarden. Each substation had high and low tension switchgear and transformers. The transformers reduced the voltage from 33KV to 3,300V part of the current was further reduced to 400V for local plants. The two main substations were inter-connected on the 3,300V side to maintain full supply in the event of the loss of one substation.

There were eight auxiliary substations at which the 3,300V current was reduced to 400V for plant use and 230V for lighting and domestic uses. Only two of these were in separate buildings, one at the central entrance to the underground chambers and one on the hillside. The others formed parts of other buildings and generally only served the building in which they were situated, in P4 and P5 there were two 400KVA 3300/400V transformers, 2 800 amp Reyrolle oil circuit breakers and a 17 panel distribution board. A 4-cylinder Pyrene CO2 fire extinguishing system protected them. Where substations served vital functions such as the pump houses or electrical distribution centres they were in splinter proof building with 14" brick walls and 7" reinforced concrete roofs.

Pump Houses

The site had three pump houses;

- Main circulating cooling-water pump house
- Emergency booster pump house
- Main effluent pump house

The main circulating cooling water pump house was part of a block with a substation, fire station and decontamination store. The pump section contained two 2,000 gall/min and one 1,000 gall/min horizontal drawing water from a sump into which flowed returned cooling water from the plant and make-up water from either the mines or the river Alyn. Mine water was delivered to the site by three (2 working, 1 standby) vertical spindle 1,000 gall/min pumps installed in a sump off the main mine drainage tunnel to the north of the site. The mine pumps were used in dry weather; in wet weather water was drawn from the river.

The emergency booster pump house had one 2,000 gall/min pump, which could be used in an emergency, which put the main pump house out of action. It could take water from the discharge of the underground mine pumps and deliver it at 250ft head to the cooling water circuit, boiler feed pumps or fire hydrants. In order to prevent mine water being inadvertently pumped into the Birkenhead supply and contaminating a drinking water supply, a section of the inter-connecting line was left uninstalled until the emergency arose.

The main effluent pump house contained three two-stage “non-clog” 1,000 gall/min pumps, which drew effluent from a 60,000 gall (273,000 litre) sump and pumped it to the river Dee outfall. One of the pumps was coupled to an oil engine for use in the case of power failure. The pumps had a 250ft head and the effluent pipe climbed 160ft above the site before draining to the Dee.

CHAPTER 5 BUILDING 45 (P6) AND THE "TUBE ALLOYS" PROJECT

Peter Bone

5.1 Introduction

Building 45 at Rhydymwyn was used between winter 1941 and early 1946 as a development unit for the Tube Alloys project. Tube Alloys was the codename for the British effort to develop an atomic bomb. It was analogous to the much better known Manhattan project in the U.S.A. and most of the scientists involved transferred to laboratories of the Manhattan project in the USA or Canada following the Quebec Agreement signed by Roosevelt and Churchill on August 19th 1943 (The Avalon Project 2006). Rhydymwyn was the UK centre for development of the gaseous diffusion process that was used to enrich natural Uranium with its more fissionable U235 isotope and make a nuclear bomb possible. The building was used for mechanical testing and development only and no radioactive materials were used on the site.

5.2 The MAUD Committee and the "Tube Alloys" Project

In February 1939 a group of scientists in Paris showed that when a uranium nucleus splits due to bombardment with a neutron (a process called fission) two or three extra neutrons are given off, this means that a self- sustaining chain reaction is possible. This reaction can occur so rapidly that a very powerful explosion results – an atomic explosion. The Paris scientists recognised that this would be very difficult with natural Uranium since the material is made up of two isotopes U235 and U238 and the U238 absorbs many of the neutrons needed to keep the reaction with the more fissionable U235 going. In March 1940 two refugee German scientists, Otto Frisch and Fritz Peirels, who had come to England and were working at Birmingham University, showed in a three page private paper, that if the lighter isotope U235, which comprises only 0.7% of the naturally occurring metal, could be separated from the heavier U238 an atomic bomb could be built with only a few kilograms of U235. Fritz and Peirels gave the memorandum to Professor Oliphant who was Poynting Professor of Physics at Birmingham working on the secret development of 10cm Radar. Oliphant in turn passed it to G.P.Thomson who was Professor of Physics at Imperial College London and the government's senior advisor on nuclear research.

A sub-committee of the Committee for the Scientific Survey of Air Warfare was set up under Thomson to consider the possibility of a Uranium bomb. This committee decided to use a camouflage name to avoid suspicion and chose the name MAUD. This is variously referred to in later documents as Maud, maud, M.A.U.D. and MAUD. For consistency, clarity and simplicity we have chosen to use MAUD. The exact meaning of the letters is obscure; however, one theory (Clarke 1961) is that it was taken from a garbled telegram from Neils Bohr (an eminent Danish Nuclear Scientist), which referred to his English nanny Maud Ray. The MAUD report itself uses M.A.U.D in its title which suggests, alternatively, that they were initial letters. U.D is thought to refer to either Uranium Development or Detonation, and M.A. probably refers to Ministry of Air (Clarke 1961).

The MAUD. Committee was given a brief:

> 'To examine the whole problem, to coordinate work in progress and to report, as soon as possible, whether the possibilities of producing atomic bombs during this war, and their military effect, were sufficient to justify the necessary diversion of effort for the purpose.'

Clarke 1961

It began several lines of research and recruited many eminent scientists some of whom would later work at Rhydymwyn. Many, including those at Rhydymwyn, transferred to the Manhattan project in 1943 and made a significant contribution to the work at Los Alamos, Chalk River in Canada and other sites (Fakley 1983).

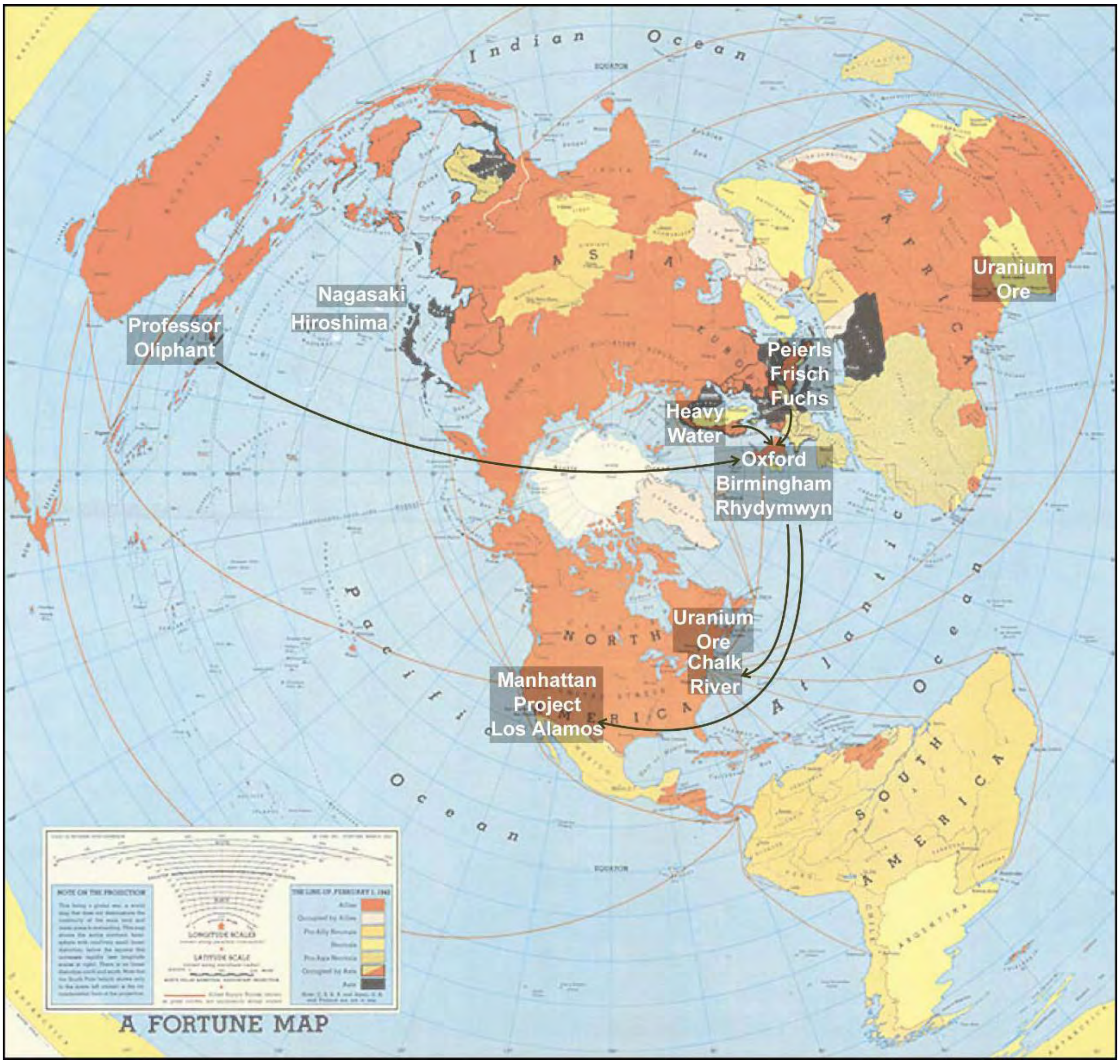


Figure 11

The separation of U235 from U238 was recognised as one of the key problems that needed to be solved. A team was formed to develop gas diffusion as a separation method, the key members were:

- Professor Simon of the Clarendon Physics Laboratory in Oxford, who lead the experimental work.
- Professor Peirels at Birmingham University who lead the theoretical work (Appendix 3).
- Professor Haworth at Birmingham University who lead the chemistry group and worked with I.C.I. on the production of Uranium Hexafluoride (UF6) and pure Uranium metal.

The MAUD Committee presented its report to Government in July 1941 (Appendix 4). The work of the committee had been exceptionally effective and the Scientific Advisory Committee to the War Cabinet stated,

> 'We have been impressed by the unanimity and weight of scientific opinion by which these proposals are supported. The destructive power of the weapon that would be created and the ultimate importance of the issues at stake, need no emphasis. Moreover we have to deal with the possibility that the Germans are at work in this field and may at any time achieve important results. It is known that one eminent German physicist in particular, Professor Hahn, has made a study of uranium disintegration for some years past…….
>
> For all these reasons we are strongly of the opinion that the development of a Uranium bomb should be regarded as a project of first class importance and all possible steps should be made to push on with the work'

(Gowing 1964)

By mid September Churchill and the Chiefs of Staff had already decided to go ahead. A new organisation was needed which moved the work from the academic to the industrial sphere. Churchill agreed that this organisation should be chaired by Sir John Anderson (Lord President of the Council) who was a scientist with a doctorate for work on uranium chemistry. Anderson appointed W.A. Akers, Research Director of I.C.I., as Chief Executive and between them they decided that the new organisation would be called the Directorate of Tube Alloys.

The name was intended to confuse the inquisitive and

> '…have a specious air of probability which might be taken by the uninitiated to have a connection with aeroplanes, radiators or tanks'

(Gowing 1964).

In its report the Scientific Advisory Committee had made a number of recommendations that it was now the responsibility of the Directorate of Tube Alloys to carry through. The recommendations included the need to press ahead rapidly with laboratory work to complete the design of a pilot separation plant and the mechanical design and construction of two ten-stage separation units which were to be assembled and tested at Rhydymwyn.

5.3 Separation of U_{235} and U_{238}

Natural Uranium metal contains 0.7% of U_{235} and 99.3% of U_{238}; the MAUD Committee report had suggested that a successful Uranium bomb would require almost pure U_{235}. The natural material therefore had to be processed to separate the lighter U_{235}. There were, at the time, several methods of achieving this separation but on the recommendations of Professor Simon, the Tube Alloys project concentrated on gaseous diffusion as being the most promising route at the time.

The gaseous diffusion process depends on the fact that lighter molecules will diffuse through a porous membrane at a slightly faster rate than heavier molecules. If the gas that diffuses through the membrane is pumped away it will become "enriched" by the lighter molecules. In order to produce the Highly Enriched Uranium (HEU) that is almost pure U_{235} nearly two thousand stages are required (Appendix 2 to the MAUD report in Gowing 1964), these are established as a counter-current process as illustrated in the diagram below. The waste from each stage is returned to the stage before and becomes "depleted" Uranium.There are three basic requirements if this process is to work:

1. A gaseous compound of Uranium is required. The only practical compound is Uranium Hexafluoride (UF6) usually called "hex". It has a triple point (simultaneously

a solid, liquid and gas) at 64oC and slightly higher than atmospheric pressure, so it can be transported as a solid and heated to produce a gas. It is toxic, reacts violently with water and is corrosive to most metals.

2. A suitable membrane material. The barrier has to be resistant to "hex" have millions of very fine holes to allow the passage of the lighter isotope and yet be strong enough to resist the gas pressure.
3. Compressors to circulate the "hex" around the system. These must be efficient, corrosion resistant, leak proof and have efficient seals between compressor and motor.

These are arduous requirements and were a major challenge to the science and engineering of 1940. Before the Tube Alloys Directorate had been established Metropolitan-Vickers had been given a contract to design and build the diffusion units.

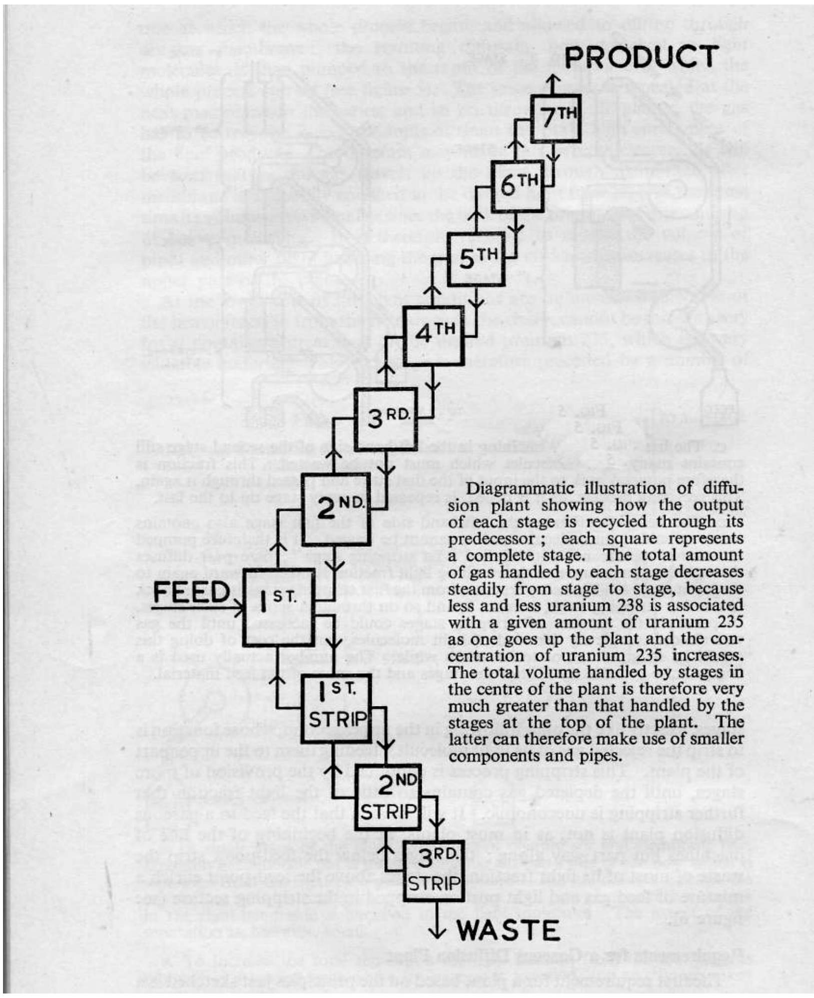


Figure 12 From Jay 1954

At the end of 1941 I.C.I was given a contract for the development of the plant as a whole, drawing up flowsheets, investigating materials of construction and developing instruments (Jay 1954). Estimates given by I.C.I. in the MAUD report suggest that the final plant would require five buildings 320 ft by 80 ft each housing 400 units and the estimated power consumption would be of the order of 40,000 kW for the site as a whole.

5.4 Work in Building 45 at Rhydymwyn

The contract with Metropolitan-Vickers was for one two stage unit and two ten-stage units. At the beginning of 1942 concern grew about the design of the machines and it was agreed to add two single stage machines to the contract to test the hydro-dynamics of the compressors. It was originally planned that these machines would be installed at Professor Simon's laboratory in Oxford, but it was realised that the project was becoming too big for a wartime University laboratory to run. It was decided to use the redundant Building 45 (P6) at Rhydymwym for the development work on the units and the work was entrusted to the I.C.I. team at Billingham under the overall control of Major Gordon. The scientists were not happy with this but an uneasy compromise was reached, I.C.I. were to be responsible for the erection and running of the machines, the research programme was to be directed by Professor Peirels (Birmingham) and Professor Simon (Oxford). (Gowing 1964)

Metropolitan-Vickers had estimated in December 1941, before the single stage machines had been added to the programme, that the two-stage machine would be installed and running at Rhydymwyn by August 1942. This machine was required to test the pumps and impellors and the basic membrane assembly. The two ten stage models were to be installed in October and December 1942. The ten stage machines would have used hexafluoride to gather information on gas flow, separation efficiency, membrane performance and plant control (Gowing 1964). This information was needed for the design of the pilot plant. The programme was seriously delayed. The first of the single stage machines did not run until New Year's Day 1943, and experiments on the two-stage machines did not start until August 1943, a year late. The two ten stage machines never ran at all. They were delivered to Rhydymwyn in November 1943, after the signing of the Quebec Agreement on Nuclear Cooperation between Roosevelt and Churchill on 19th August 1943 (The Avalon Project 2006). The machines were installed and tested but major experimental work was stopped as a result of the policy decision. There are references (Fakley 1983) that the British gas diffusion team returned to the UK in autumn 1944, and an indication that hydrodynamic and vacuum work continued at Rhydymwyn until the establishment of the Atomic Energy Research Establishment at Harwell in 1946 when the equipment was dismantled and transferred there. It may be that the equipment was later transferred to Risley and Springfields according to Jay,

> 'The first step towards designing the (gas diffusion) factory was taken early in 1948 by setting up a small team at Risley to examine the designs and flowsheets prepared under the tube alloys contract by I.C.I. Billingham from 1943 to 1945 ………. With the renewal of interest on a wider front I.C.I. effort was increased and it was decided to set up a pilot plant at the Production Division's factory at Springfields to test a single stage of the proposed equipment.'

(Jay 1954 p49)

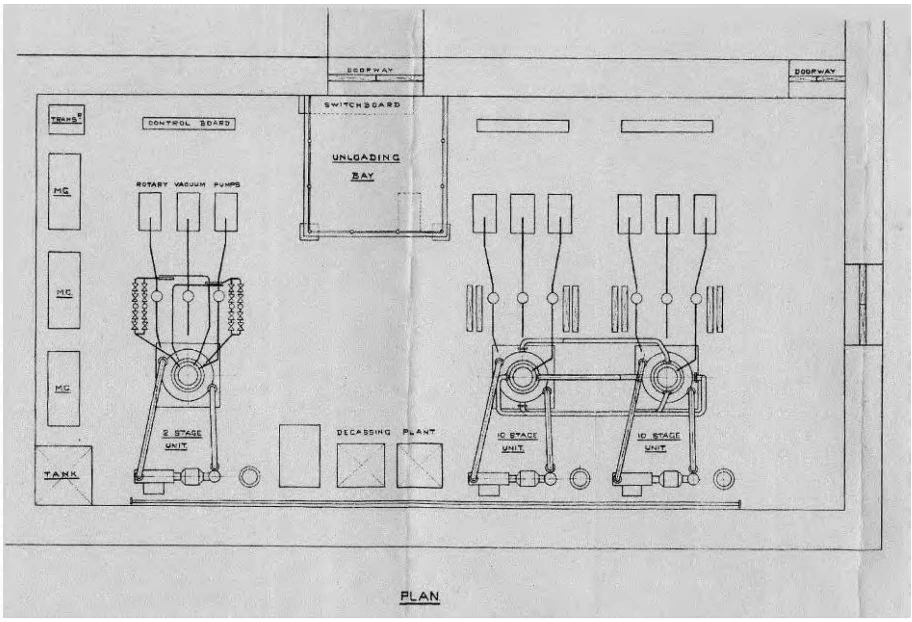
The Worlds first commercial diffusion plant was built at Capenhurst near Chester. Construction began in 1950 and the plant began operation in 1953, it ceased operation in 1982 and is being decommissioned.

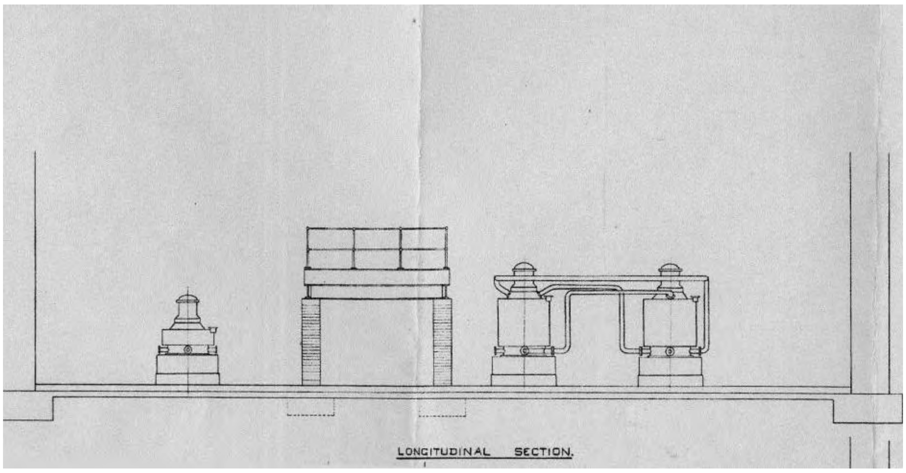
5.5 The Arrangement of the Machines in Building 45

The documentary evidence (Gowing 1964) shows that five machines were installed in building 45 at Rhydymwyn:

- Two single stage machines
- One two-stage machine
- Two ten-stage machines

Professor Simon's appendix to the MAUD report (Appendix IV – Remarks on the Separation Plant) has a discussion on the size of the ten-stage units and their throughput. A copy of a layout drawing by Metropolitan-Vickers (below) from the National Archive shows an arrangement for installation of one two-stage and two ten-stage machines in building 45. The machines are quite heavy, weighing around three tons each. They would have to have been assembled at Rhydymwyn and tested both electrically and mechanically before any experimental programme could begin. Mechanical testing would have included some hydro-dynamic testing and there is some suggestion that Sulphur Hexafluoride (SF6) which is a non-toxic, non-flammable gas often used in electrical apparatus and fluorocarbons were used (Tube Alloys 1941-45).





Figures 13a and 13b

Interpolating between the drawing and the appendix, the two-stage and ten-stage machines are of the same diameter but different heights. The impellor diameter is stated in the M.A.U.D report to be 72 centimetres; the report also gives a diagrammatic representation (not to scale) of the flow from the impellor through the membrane and between stages. This would give an estimate of about 1.2 metres for the overall diameter of the compressor casing at the base.

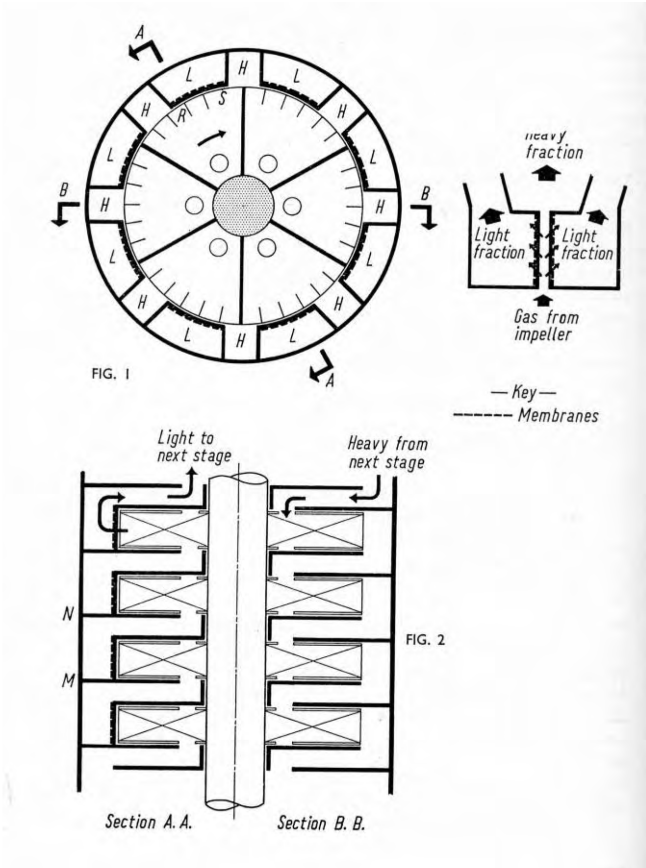


Figure 14

The total machine space shown on the plan and used by the two and ten-stage machines would be approximately 17 metres by 9 metres. This would have meant that the machines were installed in the central chamber of the building. Their weight and the need for stability when running would have required a significant foundation plinth that may be revealed if a ground penetrating radar survey of the building floor can be carried out. The area where the reactions cubicles would have been on the original design for the building would have had the door openings replaced by windows and been used as offices and smaller workshops or laboratories for the scientists. . There is a section of this wall that has a personnel door and the wall next to it is painted in a green paint. It is possible that this was the main personnel entrance the building. Half the building may not have been used before the project was transferred. It was intended to test with “hex” but this never happened. This would have required chemical plant to be installed even though the material was manufactured elsewhere. The building was within its own security fence and personnel were kept entirely separate from those working on the chemical weapons site (Clarke 1961). There are minor references in the Porton Down desk study (Pearson 1996) that there was also a separate workshop facility associated with the building. The culverted river is immediately behind Bldg 45 and there is some evidence of a bridge across to air raid shelters on the hillside opposite. The diagram below shows a possible internal layout, further investigation in the building is required to positively identify these and other features and account for the ventilation system still extant in the building.

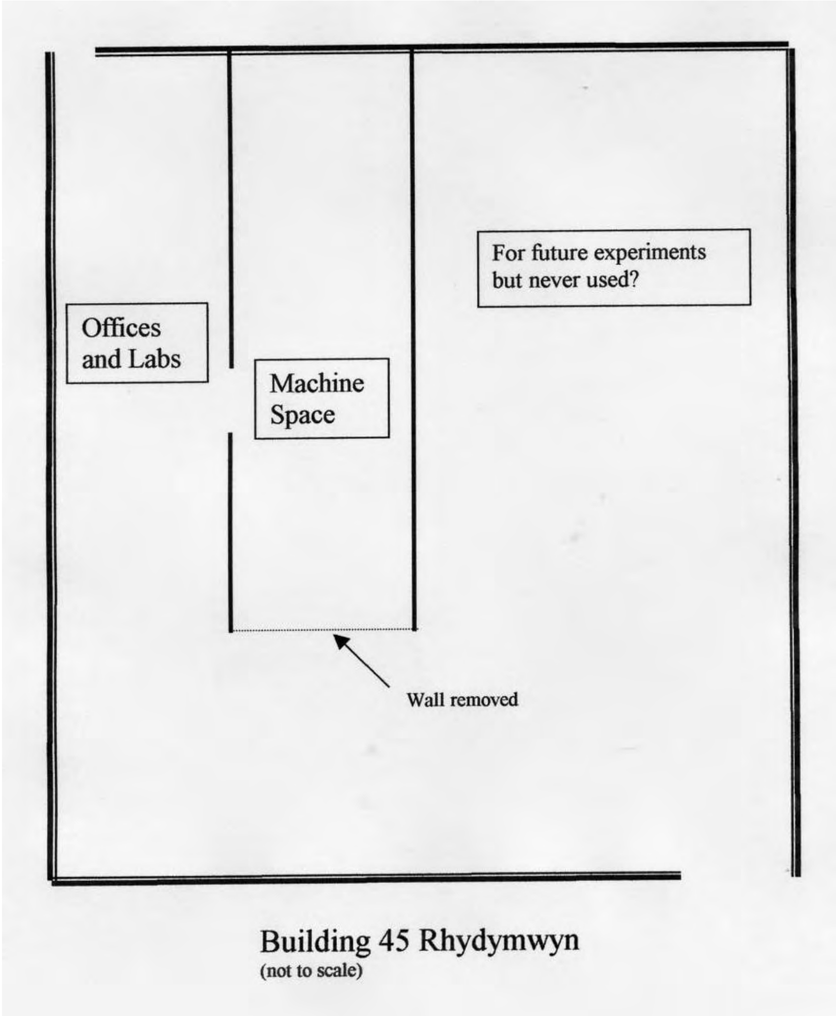

For future experiments
but never used?
Offices
and Labs
Machine
Space
Wall removed
Building 45 Rhydymwyn
(not to scale)

Figure 15

Appendix I

Gazetteer of documents relating to the site and their location

Box No. / Location	Type of document	Document Reference	Title/Subject of Document	Date of document	Quality	Description of Document (if required)
Rhyd01	Plans, lists and correspondence		Valley Plans, lists and correspondence relating to the tunnels and stored materials	1960	Primary for post war period	
Rhyd01	Inventory	V/SPS/30A	Inventory MSF Valley	1948	Primary but not as good as 1944 inventory with later notes of fate of material after war	Inventory as at 30.6.48 (2 copies)
Rhyd01	Tech Report	V/TECH.1-V/TECH.9	MSF Valley Monthly Technical Reports	May 1942-Dec 1942	Primary	
Rhyd01	Tech Report		MSF Valley Monthly Technical Reports	Jan 1941-Mar 1942	Primary	
Rhyd01	Reports		MS/CD Files Monthly Reports of Weapon Charging & Smoke Production	Dec1944-July 1945	Primary	
Rhyd01	Minutes	MS/K/1- MS/K/37	Vesicant Charging Committee Minutes	Dec 1941-Dec 1944	Primary	
Rhyd01	Minutes	MS/OD/98-109	Operations Dept. Committee Minutes	Mar 1945-Mar 1946	Primary	
Rhyd01	Misc Papers		Valley Tunnel Storage Section; Inventories, Disposal details, Signing off papers	June 1956-July 1960	Primary	
Rhyd01	Notes and summary		Valley Clean Up and Transfer	1946-48		
Rhyd02	Minutes	C&M. 1-77	Minutes of meetings held at MS Factory, Randle	Mar 1945-Aug 1957	Primary but mainly about Randle	
Rhyd03	Correspondence and report on contamination	ITEM 1 20629001/D24	Papers covering investigation of levels of contamination	1985-87	Secondary - some mistaken inferences and omissions in knowledge apparent	Letters referencing proposed land sales etc and surveys undertaken by DCES (Chemical Defence Establishment) and LGC (Lab. Of Governement Chemist), including fee notes. Notes on Aerial photographs.
Rhyd03	Photographic Record for the Contamination Report	ITEM 3	Contaminated Land Investigation Photographic Record, Part 3, Appendix C	1987	Primary for ground conditions	Details of test pitting - shows the bases of gas holders etc, inside the caverns, ammunition excavated from the site.
Rhyd04	Aerial Photographs	ITEM 6	Aerial Photographs x 2	1947	Primary	FP CPE/UK/1996 13 April 47, 1407 and 1408
Rhyd04	Correspondence and plans of toxic waste pits	ITEM 7	Toxic Waste Burial Grounds Survey	1979-1985	Secondary - some mistaken inferences and omissions in knowledge apparent	Inc 1:1250 plans
Rhyd04	Catalogue of plans for the site	ITEM 9	Register of Drawings held at Area Works Office - Corsham	1975		N.B. These include detailed building plans that are nolonger with the site archive
Rhyd04	Aerial Photographs		Aerial Photographs x 2	1946	Primary	RV 3G/TUD/192 9 May 46, 6012 and 6013
Rhyd04	Site Plan	Drg J42401	Site Plan	Revised 1948	Primary	With revisions
Rhyd04	Inventory	ITEM 12 V/SPS/30	Inventory for MS/CD Factory, Valley, Rhydymwyn, Nr Mold, North Wales as at 31/12/1944	1944	Primary	Incs details of decommissioning post war
Rhyd04	Report	ITEM 8 Report No. FGE/1016	Geotechnical Report, Rhydymwyn Storage Depot - Subsidence	1979	Primary Investigation data but some apparent mistaken inferences	Full report with plans

Box No. / Location	Type of document	Document Reference	Title/Subject of Document	Date of document	Quality	Description of Document (if required)
Rhyd04	Correspondence	ITEM 10	Effluent Correspondence	1950-1958	Primary for post war period	
Rhyd04	Site Plan	Drg J42401	Site Plan	1944	Primary	Without revisions
Rhyd05	Report	ITEM 15	Decontamination and Clearing Up the Tunnel Storage Section and Laboratories between 1954 and 1960	1960	Primary but brief, bland and possibly sanitised	
Rhyd05	Correspondence and report	ITEM 19	PCB Contamination Investigation	1992	Primary relating to post war incident - subsequent work carried out	
Rhyd05	Correspondence	ITEM 20	Correspondence re. Location of site archive	1996		
Rhyd05	OS Maps	ITEM 22	Historic Maps	1757-1912	Primary	1st, 2nd, 3rd Editions OS, and earlier enclosure/estate maps
Rhyd05	Report	ITEM 23	Project El Dorado. Report on Shaft Capping, Subsidence and Pollution Risks	1992	Secondary	by Welsh Water
Rhyd05	Report	ITEM 21	ADAS Preliminary Report on Site Rehabilitation to Agriculture and Woodland	1995	Primary data on ground conditions but some apparently odd results	
Rhyd05	Correspondence	ITEM 24	Borehole and Geological information	1979-1996		
Rhyd05	Correspondence		PRO information	1996		
Rhyd05	Report	ITEM 26	The Valley Factory Site, Rhydymwyn Strategy Report	1994	Secondary - some mistaken inferences and omissions in knowledge apparent and not carried out	by Drivers Jonas
Rhyd05	Report	ITEM 27	Valley Factory Site at Rhydymwyn Options Report	1994	Secondary - some mistaken inferences and omissions in knowledge apparent and not carried out	MAFF
Rhyd05	Report and plans	ITEM 18	Asbestos Survey Report	1992	Primary data on conditions at time but subsequent work carried out	Includes Plans
Rhyd06	Tech Report	V/SPS/1	Valley Works Selection of the Site	15/6/39	Primary	Report detailing evaluation of the site and proposals for development includes original photos of the site in 1939.
Rhyd06	Tech Report	V/SPS/4	Water services	10/1/40	Primary Design but not necessarily as built	Complete water services report incl heat balances
Rhyd06	Tech Report	V/SPS/5	Services for the Valley Works	22/1/40	Primary Design but not necessarily as built	Schedules for cooling and process water, steam, drainage and electricity.

Box No. / Location	Type of document	Document Reference	Title/Subject of Document	Date of document	Quality	Description of Document (if required)
Rhyd06	Tech Report	V/SPS/7	General Description	24/4/40	Primary Design but not necessarily as built	General description prior to site being built
Rhyd06	Tech Report	V/SPS/10	Design and Construction Assembly Unit	3/9/40	Primary Design but not necessarily as built	Description of the building used for the assembly of shells
Rhyd06	Tech Report	V/SPS/11	50 Ton/week Runcol plant	9/11/40	Primary Design but not necessarily as built	Flowsheets and plant item summary
Rhyd06	Tech Report	V/SPS/18	Creosote pitch fuel system	31/12/41	Primary	Report detailing the operation of the fuel burning systems
Rhyd06	Tech Report	V.P.38	Failure of Effluent Main Feb 1943	24/2/43	Primary	Report of failure , conditions of the main and repair. Includes a diagram showing ground levels of the pipe from valley works to the Dee
Rhyd06	Minutes	V.memo.4	Toxic Effluent Mtg held at Valley 9th March 1943	15/3/43	Primary	Mins of Mtg discussing effluent main to the Dee, dangers arising from failure of the main, effluent treatment.
Rhyd06	Tech Report	V.P-44	Effluent Treatment Toxic Acid from Runcol Plants	2/10/43	Primary	Description of the effluent treat process, analysis of effluent, comparison of methods of treatment
Rhyd06	Tech Report	V/SPS/30	Inventory @ 31/12/1944	30/3/45	Primary	
Rhyd06	Tech Report	V.P/L	History of Factory Activities 1940-1945	29/9/45	Primary - Key source of knowledge of wartime operation	215 Page history of the site by the wartime general manager
Rhyd06	Drawing	J42401	Site Layout 29/9/44		Primary	
Rhyd07	Report	ITEM 39 V/P/24	Experimental Results of Creosote Firing on Simon Carves Evans-Bowden Acid Concentration Plant	1942	Primary	
Rhyd07	Report	ITEM 40 V/P/30	Gravity Sand Filters Attached to Acid Concentration Plants	1942	Primary	
Rhyd07	Minutes	ITEM 41 V/P/22	Meeting to discuss modifications to the effluent pit	1942	Primary	
Rhyd07	Report	ITEM 42 V/P/21	Note on Wet Pyro M at Woodside	1942	Primary	
Rhyd07	Report	ITEM 43 V/P/23	Effluent Pit	1942	Primary	
Rhyd07	Minutes	ITEM 44 V/P/14	Meeting to discuss wet pyro M	1941	Primary	
Rhyd07	Report	ITEM 45 V/P/10	Creosote Firing for Simon Carves Evans Bowden Acid Concentration Plant	1941	Primary	
Rhyd07	Report	ITEM 46 V/P/8	Woodside Field Storage and Antelope Field Storage as a result of flooding of fields 14-21 Nov. 1940	1940	Primary	
Rhyd07	Memo	ITEM 47 V.MEMO.7	Runcol Effluent Treatment. Comparison of Caustic Liquor and Soda Ash for Neutralisation of Toxic Acid	1943	Primary	
Rhyd07	Memo	ITEM 51 V/12	Condensate Recovery	1942	Primary	
Rhyd07	Report	ITEM 50 V/17	Proposals and cost estimate for enclosing the effluent chamber	1942	Primary	
Rhyd07	Memo	ITEM 52 V/11	Description of Plant to Manufacture MgO CRUMBS	1941	Primary	Inc Plan showing 3 mills and space for additional mill
Rhyd07	Memo	ITEM 53 V/1	Underground Storage	1940	Primary Design but not necessarily as built	Includes Plans and Elevations of the caverns
Rhyd07	Report	ITEM 54 V/SPS/21	Cost estimate for laying a duplicate toxic drain inside the factory	1942	Primary	

Box No. / Location	Type of document	Document Reference	Title/Subject of Document	Date of document	Quality	Description of Document (if required)
Rhyd07	Minutes	ITEM 56 [V-WM.84]-[V-WM.112]	Minutes of the Works Managers' Committee Meetings	1946-1948	Primary - Key source of knowledge of immediate post wartime operation and decommissioning	
Rhyd07	Report	ITEM 57	Report on known or suspect toxic areas	1979	Secondary - some mistaken inferences and omissions in knowledge apparent	
Rhyd07	Report	ITEM 58	Demolition Works	1994	Proposal - not carried out	
Rhyd08	Report	V/SPS/1	Report on selection of site	15.6.39	Primary	author R.J.Wait (ICI Group)
Rhyd08	Photographs		Photographs of site inspection	recent	Primary	
Rhyd08	Report	ITEM 2	Contaminated Land Investigation, Part 1	1987	Secondary - investigation of ground conditions not reliable, many mistaken inferences and wrong conclusions. Original LGC report omits later PSA mistaken assumptions and apparent sanitisation	Produced by PSA.
Rhyd08	AP search	6	Tracings and notes of old OS maps	14.10.85	Secondary	Some remedial work required or scanning
Rhyd08	Plan @ 1:1250	8	Fire Organisation	21.4.1959		
Rhyd08	Plan @ 1:1250	10	Hachured plan of tunnels	May-80		Some deterioration of folds
Rhyd08	Plan @ 1:2500	11	Land offered for sale	Aug-88		Sale never happened
Rhyd08	Map	12	1:10,000 OS SJ 26 NW	1971		
Rhyd08	Plan	3	Late 1980s land disposal on 1:1250 base	1980s		
Rhyd09	Plan	DRG. No J.26030/21	Valley Works Survey Tanks refuse pits and building P6	c1940	Primary - Key source of information on wartime layout and infrastructure	
Rhyd09	Plan	DRG. No J.26030/1	Valley Works Survey Antelope and Gwynsaney Arms.	2.6.40	As above	
Rhyd09	Plan	DRG. No J.26030/1/1	Valley Works Survey Roadways.	27.6.40	As above	
Rhyd09	Plan	DRG. No J.26030/3	Valley Works Survey Laundry , Laboratory and Septic Tank	31.8.40	As above	
Rhyd09	Plan	DRG. No J.26030/ 5	Valley Works Survey Roadway and Buildings, TK2 & TK1	27.6.40	As above	
Rhyd09	Plan	DRG. No J.26030/10	Valley Works Survey River Alyn & Railway	11.4.40	As above	
Rhyd09	Plan	DRG No J.26030/11	Valley Works Survey Administration Offices	29.4.40	As above	

Box No. / Location	Type of document	Document Reference	Title/Subject of Document	Date of document	Quality	Description of Document (if required)
Rhyd09	Plan	DRG No J.26030/12	Valley Works Survey Assorted Buildings	15.1.41	As above	
Rhyd09	Plan	DRG No J.26030/13	Valley Works Survey Assorted Tanks and Buildings P4 & P5.	16.12.40	As above	
Rhyd09	Plan	DRG No J.26030/14	Valley Works Survey Building K5 & P4	date unclear	As above	
Rhyd09	Plan	DRG No J.26030/15	Valley Works Survey Building K4 & Railway.	6.5.42	As above	
Rhyd09	Plan	DRG No J.26030/16	Valley Works Survey Assorted Buildings 11-19.	x.3.41	As above	
Rhyd09	Plan	DRG No J.26030/17	Valley Works Survey Assorted Buildings 19-38.	27.11.40	As above	
Rhyd09	Plan	DRG No J.26030/18	Valley Works Survey Assorted Buildings 1-4.	15.3.40	As above	
Rhyd09	Plan	DRG No J.26030/19	Valley Works Survey Building 1 & River Alyn.	3.6.40	As above	
Rhyd09	Plan	DRG No unclear/20	Valley Works Survey River Alyn and Culvert.	8.2.40	As above	
Rhyd09	Plan	DRG No J.26030/21	Valley Works Survey Tanks refuse pits and building P6	c.1940	As above	
Rhyd09	Plan	DRG No J.26030/22	Valley Works Survey Assorted Tanks and River Diversion.	14.5.42	As above	
Rhyd09	Plan	DRG No J.26030/25	Valley Works Survey Assorted Buildings 11-13 & Canteen.	date unclear	As above	
Rhyd09	Plan	DRG No J.26030/26	Valley Works Survey Assorted Buildings 5-10	24.2.41	As above	
Rhyd09	Plan	DRG No J.26030/27	Valley Works Survey Water Main & Southern Boundary.	4.6.40	As above	
Rhyd09	Plan	DRG No J.26030/31	Valley Works Survey Ground Survey, Overhead Cables and North Tunnel.	undated	As above	
Rhyd09	Plan	DRG No J. 26030/32	Valley works Survey Ground Survey, Garth Adit and South Tunnel.	18.2.41	As above	
Rhyd09	Plan	DRG No J26030	Valley Works Survey Railway, Centre Tunnel & Ventilation Plant.	18.12.41	As above	
Rhyd09	Plan	DRG No J.26030/23	Valley Works Survey Railway, Culvert and North Tunnel.	undated	As above	
Rhyd10	Correspondence	GWF9126/945D96/C5	Correspondence re Conversion	1997-1999		Recent Photographs of Buildings at the former CWPF Norton Disney, Detailed Conversion Plans, including a list of buildings proposed for demolition and their functions. Also Final Inspection Report done by the Convention on the Prohibition of the Develpment, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction.
Rhyd10	Minutes of meetings	GWF9128/945D96/D1	Minutes of Meetings etc	1996-1998		Drivers Jonas Investigation documents
Rhyd10	Minutes of meetings, and strategy documents	GWF9746/945D96/C7	Strategy Documentation	2000-2001		Outline strategy plans, inc. remediation plans, several drafts
Rhyd10	Employers Requirements	GWF11006/61P2/A7XA	Phase 1 Remediation Work (Tender)	2002		Employers Requirements: Improvement Works at Valley Factory Site (Frances Graves Ltd)
Rhyd10	Maps and Plans	GWF11006/61P2/A7XB	Phase 1 Remediation Work (Tender)	2002		Architects plans etc for current security block
Rhyd10	Licences for access	GWF11006/61P2A7	Phase 1 Remediation Work (Tender)	2002		Licences for access
Rhyd10	Minutes of meetings	GWF10932/61P2/D1	Phase 1 Remediation Work (Minutes)	2002-2003		Estate Management - day to day running of the site
Rhyd10	Finance documents	GWF10931/61P2/C10	Phase 1 Remediation Work (Costings)	2002-2003		Financial Statements for remadiation, demolition etc
Rhyd10	Various Correspondence	GWF10930/61P2/C3	Phase 1 Remediation Work (Correspondence)	2002-2004		Environmental Remedial Works 2003, General correspondence, safety plans, GIS printouts for proposed demolition programme, architects plans for new build overlying old plan.
Rhyd10	Correspondence	GWF10929A/61P2/C1A	Phase 1 Remediation Work (Correspondence)	2004		Considerate Construction Award

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Rhyd10	Ecological Correspondence	GWF10929/61P2/C1	Phase 1 Remediation Work (Correspondence)	2002-2003		Documentation regarding survey of the caverns by Wardell Armstrong. Species Lists. Report on Ecological Works by Cheshire Ecological Services. Docs relating to the opening of the new centre. Quotations and detailsd for the production of the site video. Details of the Community Award nominations. Building Regs etc for the new build. Submission of Phase 1 remediation docs. Protected Species Audit. Citex costings. Organisational details of public meetings and matters arising. Contacts for grant applications.
Rhyd10	Finance documents	GWF10928/61P2/E12	Phase 1 Remediation Work (Finance)	2002-2003		Final account, Francis Graves Ltd
Rhyd11	Correspondence, Reports	GWF 9122A	General Correspondence	1996-2002		Assorted Correspondence to and from DEFRA. Re Antelope Business Park. Re Flooding in November 2000. Water Monitoring Data. To and from MAFF
Rhyd11	Correspondence	GWF 9126A	Correspondence re Conversion	2000-2005		Re Joint Arms Control Implementation Group visit, April 2003. Re Demolition Works
Rhyd11	Correspondence	GWF 9127	Minister's and MP's Correspondence	1996-2002		Re Flood protection/alleviation measures, including insurance premiums. To and from MAFF Remediation & sale of site. Bid for Remediation Monies in the 2000 Spending Review (unsuccesful).Parliamentary Question April 1996
Rhyd11	Correspondence	GWF 9125	Correspondence (Var)	1995-2002		To and from MAFF/DEFRA. Re Contamination, Press reports. Flintshire County Council Landscaping Brief [2000] (Photocopy). To and from CADW re possible Listing (unsuccessful). Outline Specification for Phase 1 Remedial works with confirmation of successful application (April 2002)
Rhyd11	Reports		Stage 2 Investigations.	1997-8		Stage 2 Investigations, Valley Site, Rhydymwyn (Nov 1998) AEA Technology. Detailed Report by J.H.G. Cruickshank. Environmental Appraisal (July 1997) Nicholas Pearson Associates
Rhyd11	Assorted Maps, Reports and Plans		Maps, Reports and Plans (Var)	1987-96		Article from Clwyd Historian (1996); The Role of Rhydymwyn, Clwyd in Nuclear Warfare by Tim Jones (Photocopy). Contaminated Land Investigation. Photographic Records, Dept Environment PSA (Jan 1987) Many colour photographs of excavations in progress including Tunnels. Factory plan showing Former River course [Figure 9];Factory plan (Old Building Numbers) [figure 10, Dec 1948, DRG J.42401] (duplicate), Interesting! Site Plan (Current Building Numbers)[Figure 2]; Valley Factory Site, Rhydymwyn Hydrogeology Drawing No1 (1:2500). Map showing Effluent Pipe line and former route of Birkenhead Water Main (1914 Edition) [Figure 14] (Black and White Duplicate). Rhydymwyn Site Plan (including Woodside). Approximate position of known Toxic Burial Pits [Figure 13]. Plan of Woodside [figure11, Dec 1948, J.42401]. Buffer Depot, Rhydymwyn, Site Layout--As Existing [June 1995]
Rhyd11	Reports and Correspondence	GWF 7638	Phase 1 Remediation Work, Notice of Proposed Development, Species Report	2002-03		Notice of Proposed development, Notice, Scheme Drawings Schedule of Works, including new Security Building by Paul Humphries [2002]. Protected Species Survey by Clive Herbert [2002]. Correspondence re Boundary Improvements [June 2003]
Rhyd11	Plans and Specificiation	GWF 9874	Phase 1 Remediation Work, Drawings & Specification	2002-03		Drawings with drawing Register Sheet; Plans and Schedule [2002]. Performance Specification [2002]. New Security Building Drawings with letter and Register [2003]
Rhyd11	Minutes	GWF 6694	Phase 1 Remedials: Liaison with Cilcain Community Council	2002-03		Minutes and papers for meeting with Reclamation Liaison Group. Constitution of Consultative Board and Long Term Management Plan
Rhyd11	Reports, Plans and Photographs	GWF 9123c	Toxic burial pits and pipeline	1995-2001	Dames and Moore EA based on incomplete understanding of site	Effluent Pipeline Outfall with Photographs [Oct 2000]. Assessment of Potential Buried munitions, Report for MAFF BY Julian Williams, AEA Technology. Correspondence re Report [Oct 2000]. Environmental Assessment for MAFF by Dames and Moore [May 1994]. Southern Tip Investigation by DERA Report with Photographs, Analyses, Dioxin results [2001]. Sampling and Analysis of Valley Factory Pipeline Outfall, Dee Estuary for MAFF BY Julian Cruickshank and colleagues [Mar 2001]. Memo on the significance of Dioxin findings in the Southern Tip by T S Linton [2001]

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Rhyd11	Reports etc	GWF 9123D	Various specialis reports on the site and buildings (mainly environmental)	1995-2001	Investigation of ground conditions by LGC not reliable, many mistaken inferences and wrong conclusions, account of production process apparently inaccurate - See review by CBD Porton Down in 1996 AEA Desk Study	Risk assessment for Safety Gates over the River Alun for DEFRA [Oct 2001] Underground Caverns at Rhydymwyn, Mold. Report on Stability Inspection [May 2002] by Wardell Armstrong.Protected Species Survey by Clive Herbert [2002]. Review of Valley Factory Groundwater Model, Chemical Analyses & Hydrogeological Data by Faulkener –Smith [2004]. Valley Factory, Rhydymwyn: Environmental Remedial Works, 2003 by Serco for DEFRA . Investigation at the Valley Factory site, Rhydymwyn by Laboratory of the Government Chemist November 1985 Trace metal and Mustard analyse with account of production process.
Rhyd12	General Correspondence	GWF 9122	Corr+D74espondence	1996-2002		Correspondence with PRO and MAFF. Also re. groundwater, borehole survey, and documents relating to estimates for site clearance and remediation.
Rhyd12	Correspondence to Consultants		Correspondence	2001-2002		Re Borehole contract and Dioxin Analysis
Rhyd12	Reports andCorrespondence to Consultants	GWF 9124A	Assorted correspondence including GIS, Effluent pipeline	1998-2000		State 2 Investigations, Valley Factory Site, Rhydymwyn. Draft Report Framework for MAFF [1998]. Sampling water from Halkyn and Milwr Tunnels including maps [1998]. Demolition of Buildings to confirm to CW convention [1998]. Demolition of Assorted Buildings by Drivers Jonas [1999]. Correspondence re MAFF Permanent Secretary vis1t [1999]. Upgrade of GIS [2000].Magnetometry study [2000]. Tender for Testing of Southern Tip, Valley Factory, Rhydymwyn [2000]. Investigation of Southern Tip Latest Response from DERA on pricing [2000]. Contract with AEA Technology for Southern Tip Investigation and sampling [2000].
Rhyd13	Written Deeds	GWF9121/945D96/A9	Copies of deeds	1998		Written copies of deeds NO PLAN
Rhyd13	Correspondence	GWF9124/945D96/C3	Correspondence to Consultants	1995-1996		
Rhyd13	Reports	GWF9123B/945D96/C2B	Specialist Reports	1998-2000		Stability of underground caverns. Military Aid to the Civic Community. Remote sensing for munitions. Plan of Toxic Pits. Clearance of the site. The Valley effluent pipeline. GIS proposals. Radiological contamination within the buildings.
Rhyd13	Reports	GWF9123A/945D96/C2A	Specialist Reports	1997-1998		Stage 2 Investigations. Decontamination Certificate for the Caverns. Newspaper clippings. Mine workings survey. Technical report on soil gas emission testing. Environmental Appraisal. Risk Based Options Report. Draft Contract Strategy. Potential Contamination Hazards and Trespassers.
Rhyd13	Reports	GWF9123/945D96/C2	General and Specialist Reports	1994-1996		Various site drawings (inc 1:500s). Desk Study Assessment (Appendices), Main Report and Executive Report. Options Report. Strategy Report.
Rhyd13	Costings	GWF9875/945D96/C10	Cost Estimates	1999-2001		Clearance Estimates
Rhyd13	Remediation Strategy	GWF9783/945D96/C8	Risk Analysis	1999-2001		Mustard Vapour Risk Assessment. Remediation Strategy for the Development Workshop. Various Earlier Drafts.
Rhyd13	Flood damage documents	GWF10209/945D96/C11	Remediation Work to Southern River Bank	2001-2003		Flood damage repair proposals - plans, correspondence. Boundary Information. Health and Safety documentation for the repair programme. Flood Damage Options Report.
Rhyd13	Correspondence	GWF10227/945D96/C12	Correspondence re. Flood Alleviation Works	2000-2003		Plans for flood alleviation works (Phases 1-4). Risk Assessment for Safety Gates over the River Alun (Citex).
Rhyd13	Finance documents	GWF9132/945D96/E12	Copies of financial approval	2000		
Rhyd13	General Correspondence	GWF9784/945D96/C9	Public Meetings	1997-2002		Hard copy of J.Cruickshank's powerpoint presentation 11/07/02.
Rhyd13	Minutes	GWF9128A/945D96/D1A	Minutes of Meetings etc	2000-2001		

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Rhyd14	Plans	Bundle 1	Large scale plans of survey data (all on GIS)			
Rhyd14	Maps and Plans	Bundle 2	Hard copies of OS landline data overlaid with the results of the geophysics. NB. This was done twice - the final corrected version has been integrated onto the GIS.			
Rhyd14	Plans	Bundle 3	Misc plans showing boreholes etc (all on GIS)			
Rhyd14	Plans	Bundle 4	Hard land line data (flattened copies of rolls			
Rhyd15	Series of plans		Integrated Geophysical Investigation by Reynolds Geo-Sciences	1998		5 methods undertaken: 1) Electro-magnetic ground conductivity mapping. 2) Magnetic Gradiometry. 3)Electro-Magnetic Very Low Frequency (VLF) profiling. 4) Electro-Kinetic Sounding (EKS). 5) GPR
Rhyd15	Reports		Various specific chemical tests on site and buildings	1997-2001		8 reports in total
Rhyd15	Report		Environmental Appraisal	Jul-97		
Rhyd15	Report		Report on Radiological Contamination in Building 45	1998		By Independent Radiation Assessment Services
Rhyd15	Report		Environmental Assessment	1994	Dames and Moore EA based on incomplete understanding of site	By Dames and Moore for MAFF
Rhyd15	Report		Inspection of Bridges	Feb-99		Clark and Bond Investigations. Notes that excavated material from the caves was used ot level the site and the the buildings, roads, river culvert and bridges were constructed.
Rhyd15	Reports		Series of summary reports on the Geology and Hydrogeology of the site	Nov-98		1) Summary Report on the Geology and Mining Situation 2) Final Report on the (Phase 2) Hydrogeological Investigations 3) Report on the Geology and Hydrology of the Rhydymwyn Pipeline
Rhyd15	Report		Investigation at the Valley Factory Site, Initial Ground Samples	Nov-85	Investigation of ground conditions by LGC not reliable, many mistaken inferences and wrong conclusions, account of production process apparently inaccurate - See review by CBD Porton Down in 1996 AEA Desk Study	By The Laboratory of the Government Chemist
Rhyd15	Report		Building Condition Survey	21.6.99		by Wilde and Partners
Rhyd16	Maps and Plans		Land registery deeds and land search mapping for the pipeline and areas outside the camp			
TNA	Report	WO 33/1012	Report on a Chemical Warfare Mission to America.	12/06/1922		Bound Report by J. Davidson-Pratt, Chemical Warfare Committee Office, Horse Guards
TNA	Report	WO 33/1014	Second Report of the Secretary of the Chemical Warfare Committee	1922		Details of staff changes, committee members, external work, accounts, publications, theses, work at Porton, American casualties during WWI.

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TNA	Minutes	WO 142/52	Commercial Advisory and Scientific Advisory Committee Minutes. .	28th June 1915-7th June 1916		Mainly concerned with export licences and manufacture of particular chemicals
TNA	Minutes	WO 142/72	Minutes of the Chemical Warfare Committee.	27th October 1917- 24th May 1918		
TNA	Minutes	WO 142/75	T.W.S.D. Chemical Supply Committee	13th April- 18th October, 1917		
TNA	Misc Papers	WO 142/110	Chemical Warfare Dept Files	1916-9		
TNA	Misc Papers	WO 142/196	Trench Warfare, Porton	1916-18		DES Series Files DES/1/1-35. DES Files DES/1/36-80 Includes description of plant for preparing Yperite. DES Files DES /2/141-189
TNA	Minutes	WO 142/206	Proceedings of the Trench Warfare Department	1917-1918		
TNA	Secret Minutes	WO 142/207	Proceedings of the Trench Warfare Department	1918		Secret Minutes: Advisory member; Capt. F.V. Lister OBE. Mainly technical details of weapon usage.
TNA	Secret Minutes.	WO 142/208	Proceedings of the Trench Warfare Department	1918-19		Secret Minutes.
TNA	Drawings	WO 142/221	Collection of Drawings of Shells, Bombs, etc	1915-19		Useful Information Pertaining to Design (Compiled by Major Lister)
TNA	Report	WO 142/227	Reports on Manufacture of Mustard Gas	1918		History of manufacturing methods. New method using ethylene and sulphur chloride. Problems with plant including accidents. Illnesses caused in the manufacture of Mustard Gas (H.S.)
TNA	Diagram	WO 142/245	Diagram showing History of Chemical Warfare Organisation	1915-18		
TNA	History	WO 142/249	History of Chemical Warfare Designs, etc.	1915-18		Chemical Projectile Section (and Laboratory at Wembley, i.e. C.P.L.) " In the early days of the War the laboratory apportioned to this Section, consisted of one room in a small, isolated labourer's cottage, standing inside the grounds as Wembley, which had been taken over by the then Trench Warfare Department for an experimental station."
TNA		WO 142/251	Chemical Warfare Record of Chemical Supplies for Offensive Purposes	1918		
TNA	Report	WO 142/264	Crossely Account of Porton Down	1919		Detailed account. List of officers serving at Porton.
TNA	Misc Papers	WO 142/265	Porton Down, Crossely Papers, Misc. Papers	1919-1956		Royal Society Obituary of Arthur Crossley (1869-1927).
TNA	Misc Papers	WO 142/266	Various Documents relating to Chemical Weapons	1917-19		Account of first gas attack. Detailed account of response and anti gas developments
TNA	Misc Papers	WO 142/280	Collection of Papers by Col. Kent	1915-18		Nomenclature: Green Gas (Phosgene or CG); White Gas (NC, lachrymatory gas); Yellow Gas (Mustard Gas or HS). Notes on use and properties
TNA	Diary	WO 142/281	Diary of Prof. H. Brereton Baker	1915		Diary written about his journey with Dr. J.S. Haldane to site of first German Gas attacks.
TNA	Notes	WO 142/310	Tests on Shells and Bombs	1918		Concentration of chemicals after test firing. Notes on analytical methods
TNA	Notes and lists	WO 142/311	Field-Tests on Bombs and Shells	1918		Concentrations of chemicals after test firing, Lists observers
TNA	List	WO 142/334	Roll of Officers of the Special Brigade			List of officers with profession and Record of Service (Lister and Wilson not mentioned).
TNA	Article	WO 142/335	The Work of the Royal Engineers in the European War	1914-1919		Chemical Warfare. The Royal Engineers Journal (1921) Vol. 33, p105-120
TNA		WO188/80	D.M. and Analogues: Phenylarsine	1925		Synthesis and characterisation of analogues by Prof. Gibson, Chemical Laboratory, Guy's Hospital. Irritant arsenical smoke. Led to development of GS Respirator
TNA	History	WO 188/785	Brief History of Porton	1961		Brief history not including names of staff. Useful account
TNA	History	WO 188/802	A History of Porton (1960) by L. Col. A E Kent	1877-1972		Published Ministry of Defence April 1960: Brief history of Kent's career. Bound copy of Kent's typescript published in 1992. Reference to earlier Trotman's version declassified in 1987.Rather long-winded account of events from first German gas attack upto Porton, post WWII. " It is likely that the Germans wished, as time went on, that they had never started this form of warfare!"(P 28).
TNA		AVIA 22/1711.	Ministry of Supply Factory, Valley, Rhydymwyn: Construction	1939-1943		Semi-sorted bundle of papers.
TNA	Misc Papers	AVIA 22/1712	Ministry of Supply Factory, Valley, Rhydymwyn: Construction	1943-48		

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TNA	Correspondence	AVIA 22/1713	Ministry of Supply Factory, Valley, Rhydymwyn: Site and Layout,	1939-1947		Assorted correspondence concerning the site
TNA	Assorted correspondence	AVIA 22/1714	Ministry of Supply Factory, Valley, Rhydymwyn, Planning of Assembly Unit	1939-41		
TNA		AVIA 22/1715.	Ministry of Supply, Valley, Rhydymwyn; Care and Maintenance,	1945-8		Main Factory in the course of de-contamination, the Tunnel Storage will be retained for the storage of toxic materials. All decontamination work completed by 30th June 1948. Details of decontamination including sea dumping.Care and Maintenance Reports. Decision to take over site by Ministry of Supply at the end of 1947. Letter form ICI that they wish to be completely free of responsibility for the site from the end of 1948.Transfer of four Ethylene Gas Holders to the Department of Atomic Energy (30th July 1947)
TNA		AVIA 22/1965	Ministry of Supply Factory, Valley, Rhydymwyn: Modification for use by D.I.S.R.	1942-6		
TNA		SUPP 5/1003	History of Imperial Chemical Industries' War Effort.	1944		Construction of Ministry of Supply/Chemical Defence Factories Vesicant Section Part I: Construction of MSF Randle Part II: Construction of MSF Valley Part III: Construction of MST Springfields Part IV: Construction of Forward Filling Depots
TNA		SUPP 5/1011	Valley: Factory Activities	1940-45		Paper by R. Thomas on detailed working of Factory
TNA		PREM 3/139/8A	Tube Alloys	1941-45		
TNA		HLG 47/684	Rhydymwyn Housing Issues	1919-1921		Application under State-aided Housing Scheme at Pasture field adjacent to Rhydymwyn Station. Includes plan showing site between Station and River Alyn with effluent from septic tank and disused lead mine adjacent to Factory site (Dated 21st Dec 1921).
TNA		HLG 49/837	Proposed Housing Site at Rhydymwyn	1925-7		Site close to Rhydymwyn Station for 22 houses: Holywell RDC Housing Scheme. Application (26/2/1926) by Holywell RDC under Section 3 of the Housing (Financial Provisions) Act 1924 for a loan of £12,804 including £625 for septic tank and filter bed and £400 for architect fees to the Ministry of Health. Plans of site and housing with plan showing site prior to erection of Valley Factory.
TNA		AB 1/68	M.S. Factory, Valley Flintshire Metro-Vickers Models Ltd	1941-45		Assorted correspondence.Maes Alyn Hostel: Use by and retention after closure of Project X. Letter dated Mar 1942, "Prime Minister and he has appointed Mr. W.A. Akers (DSIR) to take executive control of the project" Plan of arrangement of Compressors and Auxiliaries (Feb 1942) Requirements (Dated Feb1942): Three main machines each weighing 3 tons Plan and diagram of the one 2-stage and two-10 stage Units (Jan 1942)
TNA		AB 1/69	MS Factory Valley Flintshire Drawing	1942-45		No Actual Drawings in the File
TNA		AB 3/8	MS Factory, Valley Flintshire, Vacuum Techniques Minutes	1943		Testing of Valley Vacuum Technique (Oct-Nov 1943).
TNA		AB 3/23	MS Factory, Flintshire-goods sent to and from	1942-3		List goods ordered for Valley and Suppliers
TNA		AB 3/76	Clarendon Laboratory –Valley Co-operation and meetings	1942-43		
TNA		AB 3/77	Clarendon Laboratory –Valley Co-operation	1943		Letter dated 25th February 1943 concerning differences between ICI and Clarendon Laboratory Staff
TNA		AB 16/266	Organisation: History of Tube Alloys and its Development	1941-2, 1949-52		Maud Committee: Final Report (July 1941) Issues and conclusions relating to the production of an atomic bomb.
TNA		HW 1/3717A	Tube Alloys	1945		Piece withheld (1994).
TNA		FD 1/6702	Industrial Toxicology: toxicology and tube alloys	1943-7		Correspondence with MRC concerning toxic risks for workers on Tube Alloys Project

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FRO	Extracts	NT/1319	Extracts *from* The Birth of the Bomb by R.W. Clark: London ; Phoenix House Ltd	1961		The untold story of Britain's Part in the Weapon that changed the World. References to work at Rhydymwyn 1942-3. Maud Committee met at the Athenaeum. Reference to 'plant for making artificial rubber'. Entry of America into the War overshadowed the work of Tube Alloys. Development –plant for testing individual components built at Rhydymwyn. ICI produced the membranes and Metropolitan Vickers produced the prototype equipment in which they were used. Collaboration between the Oxford Group under Simon and ICI under Smith at Witton began in early 1941. Details of experiments and results. Use of bromoform and iodine for testing efficiency of the membranes. References to work carried out at Rhydymwyn
FRO	Extracts	NT/661	Extracts on Valley Factory *in* Britain and Atomic Energy 1939-45	1964		by Margaret Gowing: London; Macmillan & Co Ltd. Account of process including gaseous diffusion. Original contract with Metropolitan –Vickers for 1 two-stage and 2 ten-stage units. Erected early in 1942 at Valley as more convenient for Metropolitan Vickers and for ICI than assembling the unit at Oxford. Controversy over roles of ICI and their responsibility. Delays in delivery of equipment until mid 1943. Much work on the associated machinery and lubricants. Americans suggested use of fluorocarbons as lubricants. Valley models concentrated on membranes for the diffusion process. The ten-stage model was never used. 'The work was unhappily poised between the stages of university research and full industrial development. The ICI men found the organisation of the research hopelessly diffused and wanted the work concentrated under a single director while the university scientists felt that research was so fluid that it was undesirable that those engaged on it should be in any way restricted by anyone with dictatorial powers' Reasons for relative failure of the programme.Detailed account of US involvement and British collaboration. UK contribution mainly on fundamental w
FRO	Correspondence	NC 559	Letter Regarding the Secret War Time research at the Government factory at Rhydymwyn	1982		Letter to local Newspaper by J.G. Gardner claiming that plant used for Heavy Water production. Of little interest
FRO	Misc Papers	FC/C/6/1160	File re Ministry of Works Storage Accommodation	1943		Correspondence between County Surveyor and Ministry of Works Estate Surveyor re Storage programme
FRO	Correspondence	FC/C/6/382	Correspondence re War Factory	1936-44		Correspondence re employment issues in Mold. Possibility of an Aircraft Factory at Broughton: Correspondence with various manufacturers relocating to region and aircraft assembly plants. High unemployment in North Flintshire. No direct reference to Rhydymwyn (Photocopies of two relevant letters).
FRO	Report		Microfiche Copy of PRO SUPP5/1011 History of Factory Activities 1940-1945 by R. Thomas (Factory Manager 1940-1945) (1945	1945		
FRO	Map	D/GW/655	c1757 Map	1757		
FRO	Map	D/GW/693	Plan Lands and tenements in township of Hendrehoffa and Gwernaffillt dated 1820 – Scale 6.6inch to 1 mile.	1820		
FRO	Lease	D/GW/588	Lease PBDC to JT dated 30th December 1827	1827		
FRO	Correspondence	D/GW/594	Letter from JT to PBDC dated 4th March 1839	1839		
FRO	Correspondence	D/GW/594	Letter from JT to PBDC dated 26th September 1862	1862		
FRO		D/GW/B/594	Value of Equipment Left at Mold (Rhydymwyn) Foundry			
FRO	Drawing	D/HM/218	Pen-y-fron and Rhyd-y-mwyn Mine Section, Scale 1 inch to 10 fathoms	1827		listed as late 19th Century, but more likely to be circa 1827- similar to D/HM/215 dated 1827
FRO	Plan	D/GW716	16th January 1850 Plan	1850		
FRO	Plan	D/GW/723	31 August 1859 Tracing	1859		
FRO	Plan	AB 145	Abandoned Mine Plan	1914		
FRO	Plan	AB 113	Abandoned Mine Plan			
FRO	Plan	AB 114	Abandoned Mine Plan			
FRO	Drawing	D/GW/612	Section of Rhydymwyn Lead Mine	1836		

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FRO	Plan	D/HM/215	Section Plan of Pen-y-fron and Rhyd-y-mwyn - Mold Mines	May 1827		
FRO	Plan	D/HM/220	Rhyd-y-mwyn Mine, plan of mine from Dyers Shaft to Iron Shaft late 19th Century.			Scale 1 inch to 10 fathoms
FRO	Photograph	55/1	Nant Alyn			Postcard
FRO	Photograph	55/2	Parish Church	1908		Postcard
FRO	Photograph	55/3	Nant Alyn Bridge	1905		Postcard
FRO	Photograph	55/4	Nant Alyn			Postcard
FRO	Photograph	55/5	Plaque commemorating Mendelssohn's Visit			
FRO	Photograph	55/6	Coed Du Hall			
FRO	Photograph	55/7	Rhyd y Mwyn Mill			
FRO	Photograph	55/8	Flooding in Leete Road	1935		
FRO	Photograph	55/9	New Post Office	1938		
FRO	Photograph	55/10	Women'd Institute Group	1920		
FRO	Photograph	55/11	Rose Queen	1930		
FRO	Photograph	55/12	Rose Queen	1930		
FRO	Photograph	55/13	The 'Buffaloes' outside Glan yr Afon Inn, Hendre			
FRO	Photograph	55/14	Hendre Quarrymen			
FRO	Photograph	55/15	Royal Oak Inn and Shop	1915		
FRO	Photograph	55/16	Red houses, Leete Road	1910		
FRO	Photograph	55/17	Parish Church	1918		
FRO	Photograph	55/18	The Lodge, Coed Du			
FRO	Photograph	55/19	Rhyd y Mwyn Mill			
FRO	Photograph	55/20	River Alyn near mill	1926		
FRO	Photograph	55/21	Parish Church, Rhyd y Mwyn Farm and Glan Alyn			
FRO	Photograph	55/22	Glan yr Afon Inn, Hendre			
FRO	Photograph	55/23	Nant Alyn Mill			
FRO	Photograph	55/24	The Leete	1905		Postcard
FRO	Photograph	55/25	Nant Alyn Mill			
FRO	Photograph	55/26	School pupils and teachers			
FRO	Photograph	55/27	School pupils and teachers and vicar	1903		
FRO	Photograph	55/28	Hendre Quarrymen			
FRO	Photograph	55/29	Coronation Festivities Committee and Workers	1911		
FRO	Photograph	55/30	School pupils and teachers			
FRO	Photograph	55/31	School pupils and teachers			
FRO	Photograph	55/32	School pupils and teachers			
FRO	Photograph	55/33	School pupils			
FRO	Photograph	55/34	Group outside Sardis Chapel, Hendre			
FRO	Photograph	55/35	Miss G. Davies-Cooke, Bryn Alyn	1930		
FRO	Photograph	55/36	Petrol Station and Café	1930		
FRO	Photograph	55/37	Milk Lady and Cart in Leete Avenue	1930		
FRO	Photograph	55/38	New Post Office under construction	1935		
FRO	Photograph	55/39	Village	1960		
FRO	Photograph	55/40	The Vardo, Garreg Boeth	1930		
FRO	Photograph	55/41	Leete Road near Rhyd y Mwyn Farm	1900		
FRO	Photograph	55/42	St. John's Church choir	1930		
FRO	Photograph	55/43	Ladies Coronation Committee	1937		
FRO	Photograph	55/44	School children's Coronation play	1937		
FRO	Photograph	55/45	Leete Road	1937		
FRO	Photograph	55/46	Mill House Bridge and Church	1910		
FRO	Photograph	55/47	Village	1930		
FRO	Photograph	55/48	Leete Road	1937		

Box No. / Location	Type of document	Document Reference	Title/Subject of Document	Date of document	Quality	Description of Document (if required)
FRO	Photograph	55/49	Alyn Valley			
FRO	Photograph	55/50	post Office and Rhyd Alyn	pre1910		
FRO	Photograph	55/51	Glan yr Afon Inn, Hendre	1935		
FRO	Photograph	55/52	Ruby Brickworks employees			
FRO	Photograph	55/53	Ruby Brickworks employees outing			
FRO	Photograph	55/54	Dolfechlas Road during snow	1982		
FRO	Photograph	55/55	Mold-Denbigh Road during snow	1982		
FRO	Photograph	55/56-7	Leete Road during snow	1982		
FRO	Photograph	55/58	Mill House	1900		
FRO	Photograph	55/59	Hendre Village			Postcard
FRO	Photograph	55/60	Leete Avenue	1930		
FRO	Photograph	55/61	Sports Committee	1930		
FRO	Photograph	55/62	Sports Day	1930		
FRO	Photograph	55/63	Sun Inn			
FRO	Photograph	55/64	Sun Inn			
FRO	Photograph	55/65	Parish Church			
FRO	Photograph	55/66	School pupils and teacher			
FRO	Photograph	55/67	School pupils	1912		
FRO	Photograph	55/68	Leete Road	1910		
FRO	Photograph	55/69	Min y Coed, Nant Alyn	1982		
FRO	Photograph	55/70	Tennis Club			
FRO	Photograph	55/71	Nant Alyn			
FRO	Photograph	55/72	Rhyd y Mwyn Mill and bridge	1925		
FRO	Photograph	55/73	Rhyd y Mwyn Mill	1905		
FRO	Photograph	55/74	Rhyd y Mwyn Mill	1910		
FRO	Photograph	55/75	Nant Alyn Mill	1928		
FRO	Photograph	55/76	Nant Alyn Mill and shop	1950		
FRO	Photograph	55/77	Nant Alyn			
FRO	Photograph	55/78	Old Post Office			
FRO	Photograph	55/79	Aerial View	1977		
FRO	Photograph	55/80	Dairy Class at Foundry House	1915		
FRO	Photograph	55/81	Kangaroo Corner			
FRO	Photograph	55/82	Sun Inn and Mold-Denbigh Road			
FRO	Photograph	55/83	Haycart near Pren Teg, Nant Alyn	1939		
FRO	Photograph	55/84	Pren Teg and Coed Du Lodge			
FRO	Photograph	55/85	On Bridge over river Alyn			
FRO	Photograph	55/86	Rhydymwyn Mill			
FRO	Photograph	55/87	Approach to Hendre			
FRO	Photograph	55/88	hendre			
FRO	Photograph	55/89	Galn yr Afon Inn, Hendre			
FRO	Photograph	55/90-93	Hay harvesting near Rhydymwyn	1920		
FRO	Photograph	55/94	Unidentified Cottage	1920		
FRO	Photograph	55/95	Min y Coed Cottage, Nant Alyn	1983		
FRO	Photograph	55/96	Parish Church			
FRO	Photograph	55/97	Coed Du Hall	1908		
FRO	Photograph	55/98	Parish Church	1890		
FRO	Photograph	55/99	Parish Church interior	1890		
FRO	Photograph	55/100	Ruby Brick Works			
FRO	Photograph	55/101	Millhouse Bridge and Churchh	1906		
FRO	Photograph	55/102	Steam Locomotive at Hendre Quarry			
FRO	Photograph	55/103-4	Sardis Chapel, Hendre			
FRO	Photograph	55/105	Floods by railway bridge, Hendre			
FRO	Photograph	55/106-7	Peddlars Cycle Factory	1981		
FRO	Photograph	55/108	Coed Du Hall			

Appendix II

Gazetteer of early landscape features by SMR number

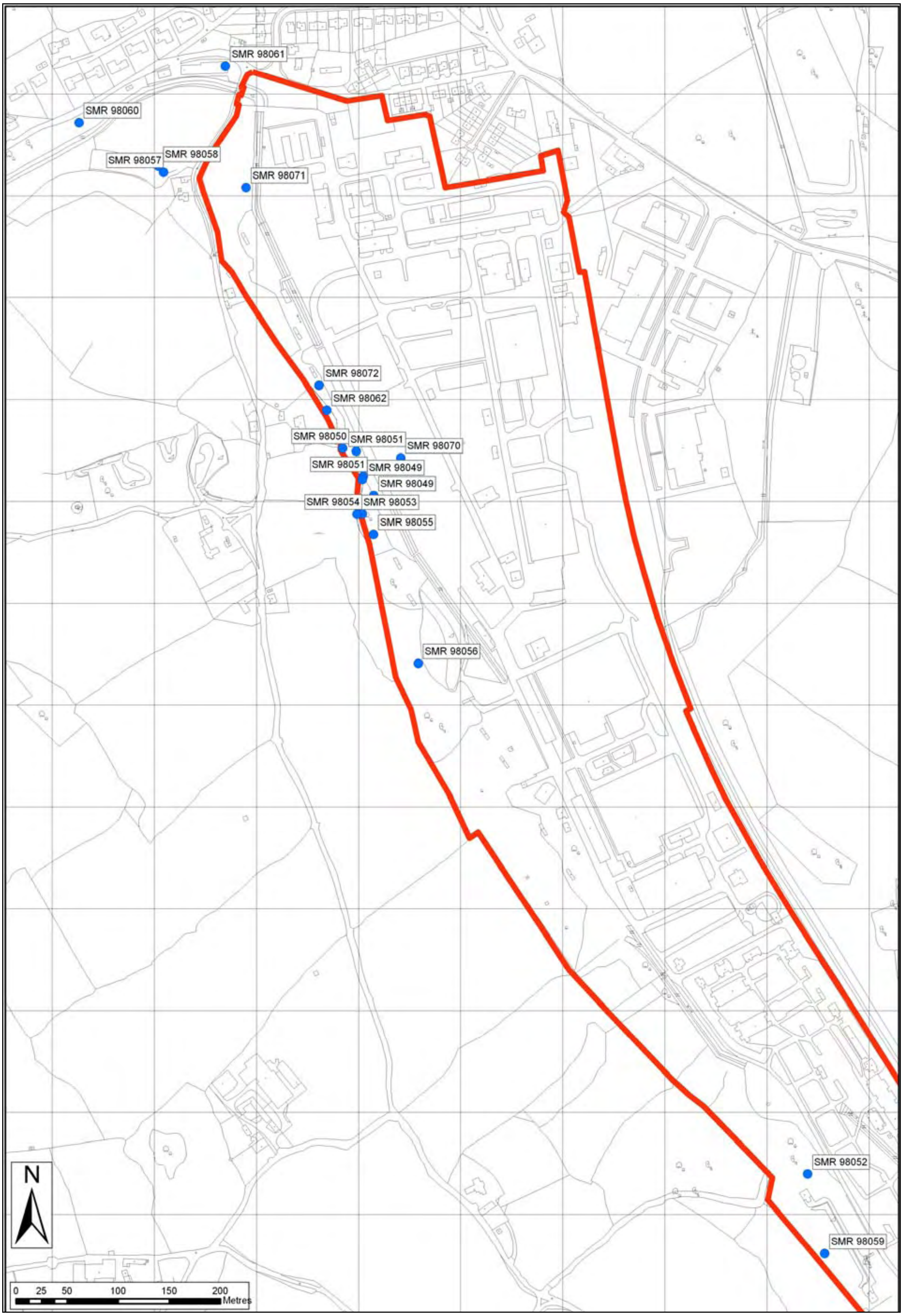

Figure showing location of features identified during the walkover survey

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98049			**NGR**	
CURRENT NO		**SITE REF**		**INVENTORY NO**	

ORIGINAL USE: Foundry wall

DESCRIPTION: Substantial wall survives to height of over 2m. Return visible at southern end. Notches visible on interior wall where beams would have been slotted to support equipment used in the foundry.

LOCATION:

GRAFFITI:

ASSOCIATED WITH: 98070

1944 INVENTORY LIST / HISTORIC MAP REF: 1859

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL	Good	**WALLS**	Good
ROOF		**ASSOC**	

SIGNIFICANCE: The earliest building surviving on the site.

RECOMMENDATIONS: Clearance of sapling trees (such as Yew) which are growing out of it. This will help to stabilse and preserve the structure. Soil from the culvert has been banked up against the eastern side, so below-ground preservation may be good.

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

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SMR 98049 Internal wall of foundry building with later buttresses

SMR 98049 Foundry building external elevation

SMR 98049 Foundry building wall

SMR 98049 Detail of foundry building wall and return

SMR 98049 Easterly return of the foundry building

SMR 98049 Detail of niche for beam

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98050
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	Trackway
DESCRIPTION	Survives only very partially within the bounds of the site. The terrace wall on the eastern side of the site does not survive well and is in danger of erosion along its upper course
LOCATION	
GRAFFITI	
ASSOCIATED WITH	98070
1944 INVENTORY LIST / HISTORIC MAP REF	1859

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL	Still operates as driveway, but is being filled in just outside line of fence by modern tipping	**WALLS**	
ROOF		**ASSOC**	

SIGNIFICANCE	This is one of the earliest routeways into the valley, and may predate the foundry.
RECOMMENDATIONS	Sapplings should be cleared from the lower section adjacent to the foundry wall so that this early feature is better displayed to users of the woodland walk, and to prevent further damage by root action.

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

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SMR 98050 Trackway inside the fence line


SMR 98050 Detail of upper revetment wall for the trackway


SMR 98050 Trackway outside the fence line


SMR 98050 Trackway running towards base of incline plain

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98051
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	Revetment wall
DESCRIPTION	Survives in places to a height of c.1m. Dry stone walling cut into the hillside. Has spoil from the cutting of the culvert piled up against it so is probably more substantial.
LOCATION	Defines the western side of the foundry complex
GRAFFITI	
ASSOCIATED WITH	98070
1944 INVENTORY LIST / HISTORIC MAP REF	1859

CONSTRUCTION MATERIAL LOCATION

CONCRETE	
STEEL	
CORRUGATED	
OTHER	

CONDITION

GENERAL	
WALLS	Some collapse in places
ROOF	
ASSOC	

SIGNIFICANCE	One of the earliest landscape features survivng in the Valley
RECOMMENDATIONS	Clearance of undergrowth so that further root damage does not occur

MAIN PLAN DIMENSIONS	
PHOTO DIG NO	
AREA	
PHOTO B/W NO	
DWG NO	
PHOTO C/T NO	

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SMR 98051 Foundry revetment wall to the north of the foundry building

SMR 98051 Foundry revetment wall with the trackway above

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98052
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	Trackway
DESCRIPTION	Visible as a hollow way, partially covered over by the creation of the anti-blast bank for the northern magazine in 1939-40. Associated with a stone gate post.
LOCATION	In the vicinity of the magazines
GRAFFITI	
ASSOCIATED WITH	
1944 INVENTORY LIST / HISTORIC MAP REF	1870

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL		**WALLS**	
ROOF		**ASSOC**	

SIGNIFICANCE	
RECOMMENDATIONS	Further documentary and oral history to be undertaken.

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98053	**NGR**	
CURRENT NO		**SITE REF**	
INVENTORY NO			
ORIGINAL USE	Incline Plain		
DESCRIPTION	Roughly 2m wide, hollow way with external banks.		
LOCATION	In field to the west of the site		
GRAFFITI			
ASSOCIATED WITH	98054, 98055, 98056		
1944 INVENTORY LIST / HISTORIC MAP REF	1912		

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL	Survives well as an earthwork	**WALLS**	
ROOF		**ASSOC**	

SIGNIFICANCE	
RECOMMENDATIONS	

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

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SMR 98053 Incline plain looking up from its base


SMR 98053 Bank for the incline plain looking south

SMR 98053 Incline plain looking east towards the Valley Site

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98054
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	Engine House
DESCRIPTION	There is very fragmentary evidence for a stone engine house at the base of the incline palin, as depicted on the 1912 OS Map. Does not survive well on the ground.
LOCATION	at base of incline plain
GRAFFITI	
ASSOCIATED WITH	98053, 98055, 98056
1944 INVENTORY LIST / HISTORIC MAP REF	1912

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL		**WALLS**	
ROOF		**ASSOC**	

SIGNIFICANCE	
RECOMMENDATIONS	

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

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SMR 98054 Structural remains at the base of the incline plain (possible engine house)

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98055
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	Waste tip
DESCRIPTION	This may be composed of rake-out from the engine house
LOCATION	at base of incline plain
GRAFFITI	
ASSOCIATED WITH	98053, 98054, 98056
1944 INVENTORY LIST / HISTORIC MAP REF	1912

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL		**WALLS**	
ROOF		**ASSOC**	

SIGNIFICANCE	
RECOMMENDATIONS	

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

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SMR 98055 Waste tip at base of incline plain

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98056
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	
DESCRIPTION	Area of possible mine shafts and waste tips made from coke ash and clinker which may have been rake out from the engine house shown on the 1912 OS
LOCATION	
GRAFFITI	
ASSOCIATED WITH	98053, 98054, 98055
1944 INVENTORY LIST / HISTORIC MAP REF	

CONSTRUCTION MATERIAL LOCATION

CONCRETE	
STEEL	
CORRUGATED	
OTHER	

CONDITION

GENERAL	
WALLS	
ROOF	
ASSOC	

SIGNIFICANCE	
RECOMMENDATIONS	Further survey work to be undertaken to identify possible shafts

MAIN PLAN DIMENSIONS	
PHOTO DIG NO	
AREA	
PHOTO B/W NO	
DWG NO	
PHOTO C/T NO	

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SMR 98056 Area of mine shafts and waste tips


SMR 98056 Possible mine shaft


SMR 98056 Area of mine shafts and waste tips


SMR 98056 Area of mine shafts and waste tips

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98057
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	Wheel pit
DESCRIPTION	Large stone wheel pit
LOCATION	in field to the west of the site
GRAFFITI	
ASSOCIATED WITH	98058
1944 INVENTORY LIST / HISTORIC MAP REF	1870

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL	Good	**WALLS**	Good
ROOF		**ASSOC**	

SIGNIFICANCE	
RECOMMENDATIONS	Further documentary and oral history to be undertaken.

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

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SMR 98057 Wheel pit from the bridge

SMR 98057 Wheel pit


SMR 98057 Detail of external elevation of wheel pit


SMR 98057 Eastern elevation of the wheel pit

SMR 98057 Detail of reinforcing bars through the eastern elevation of the wheel pit

SMR 98057 detail of masonry from the wheel pit

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98058
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	Stone Leat
DESCRIPTION	Associated with the wheel pit, still visible on the ground for most of its course.
LOCATION	Field to the west of the site
GRAFFITI	
ASSOCIATED WITH	98057
1944 INVENTORY LIST / HISTORIC MAP REF	1870

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL	Survives well, some erosion from walkers and livestock	**WALLS**	Some collapse
ROOF		**ASSOC**	

SIGNIFICANCE	
RECOMMENDATIONS	

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

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SMR 98058 Exit of the wheel pit leat from the River Alyn

SMR 98058 Stone-lined leat entering the wheel pit

SMR 98058 detail of stone-lining of the leat

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98059
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	Stone structure
DESCRIPTION	Rectangular structure c.10m x 5m. Back wall stands up to 1m high, possible evidence of a chinmey. Stands on terrace created by building up ground on slope below,
LOCATION	hillside above magazines.
GRAFFITI	
ASSOCIATED WITH	terrace walls
1944 INVENTORY LIST / HISTORIC MAP REF	

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL	Terrace cut by woodland walk	**WALLS**	Lots of collapse
ROOF		**ASSOC**	

SIGNIFICANCE	Does not appear on any maps, terrace dated by pottery to late 18th-first half of 19th century, therefore unusual.
RECOMMENDATIONS	This area is archaeologically sensitive and no further groundworks should be undertaken in the vicinity. Vegetation should be kept down here to prevent further damage by root action.

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

SMR 98059 Western elevation of structure above magazines

SMR 98059 South-west corner of the structure

SMR 98059 Detail of the rear wall of the structure, showing collapse

SMR 98059 Detail of the revetment wall for the terrace

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98060
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	Mill leat (head race for Corn Mill) and Weir
DESCRIPTION	Earthwork with bank survives on the ground. Evidence by the weir that it was stone lined. Masonry from weir survivies in-situ. Between1m-2m wide.
LOCATION	South of Nant Alyn Road
GRAFFITI	
ASSOCIATED WITH	98061
1944 INVENTORY LIST / HISTORIC MAP REF	

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL	Some erosion from walkers and bikers	**WALLS**	
ROOF		**ASSOC**	

SIGNIFICANCE	
RECOMMENDATIONS	Further earthwork survey to be undertaken.

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

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SMR 98060 Leat associated with the mill

SMR 98060 Weir and leat to the right

SMR 98060 Detail of the leat wall by the weir on the River Alyn

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98061
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	Site of Mill
DESCRIPTION	Good photographic evidence for what the mill looked like. The mill cottage still remains.
LOCATION	
GRAFFITI	
ASSOCIATED WITH	98060
1944 INVENTORY LIST / HISTORIC MAP REF	1870-3

CONSTRUCTION MATERIAL LOCATION

CONCRETE	
STEEL	
CORRUGATED	
OTHER	

CONDITION

GENERAL	
WALLS	
ROOF	
ASSOC	

SIGNIFICANCE	
RECOMMENDATIONS	Further documentary and oral history work to be undertaken.

MAIN PLAN DIMENSIONS	
PHOTO DIG NO	
AREA	
PHOTO B/W NO	
DWG NO	
PHOTO C/T NO	

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SMR 98061 New development on the site of the former mill

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98062			**NGR**	
CURRENT NO		**SITE REF**		**INVENTORY NO**	

ORIGINAL USE

DESCRIPTION Garden

LOCATION

GRAFFITI

ASSOCIATED WITH

1944 INVENTORY LIST / HISTORIC MAP REF

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL		**WALLS**	
ROOF		**ASSOC**	

SIGNIFICANCE

RECOMMENDATIONS

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

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SMR 98062 Fragment of garden

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98070
NGR	
CURRENT NO	
SITE REF	
INVENTORY NO	
ORIGINAL USE	The site of the foundry
DESCRIPTION	The site of the foundry is depicted on maps from 1757 onwards. This part of the site was never occupied by any buildings during WWII. A copse of trees marks the spot on the ground today, the roots will have impacted on any surviving archaeology.
LOCATION	
GRAFFITI	
ASSOCIATED WITH	
1944 INVENTORY LIST / HISTORIC MAP REF	1757

CONSTRUCTION MATERIAL LOCATION

CONCRETE	
STEEL	
CORRUGATED	
OTHER	

CONDITION

GENERAL	
WALLS	
ROOF	
ASSOC	

SIGNIFICANCE	
RECOMMENDATIONS	

MAIN PLAN DIMENSIONS	
PHOTO DIG NO	
AREA	
PHOTO B/W NO	
DWG NO	
PHOTO C/T NO	

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SMR 98070 The site of the foundry

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98071			**NGR**	
CURRENT NO		**SITE REF**		**INVENTORY NO**	

ORIGINAL USE: Leat for mills depicted on 1757

DESCRIPTION: Early leat marked by willows, leat nolonger visible, but occurance of willows suggests watercourse. Bank also visible immediately to the south of where the culvert branches into the underground caverns.

LOCATION: north end of site

GRAFFITI:

ASSOCIATED WITH:

1944 INVENTORY LIST / HISTORIC MAP REF: 1757

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL		**WALLS**	
ROOF		**ASSOC**	

SIGNIFICANCE:

RECOMMENDATIONS:

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

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SMR 98071 Willows marking the line of the early leat

Rhydymwyn Historic Management Plan: Building Assessment

SMR NO	98072	**NGR**	
CURRENT NO		**SITE REF**	
INVENTORY NO			
ORIGINAL USE	Boundary Wall		
DESCRIPTION	Fragment of stone wall, continues outside fence line. Survives to a height of c.2m. Roughly 1' thick.		
LOCATION			
GRAFFITI			
ASSOCIATED WITH	Foundry?		
1944 INVENTORY LIST / HISTORIC MAP REF	1870-3		

CONSTRUCTION MATERIAL LOCATION

CONCRETE		**STEEL**	
CORRUGATED		**OTHER**	

CONDITION

GENERAL	Good	**WALLS**	
ROOF		**ASSOC**	

SIGNIFICANCE	
RECOMMENDATIONS	Condition should be monitored

MAIN PLAN DIMENSIONS		**PHOTO DIG NO**	
AREA		**PHOTO B/W NO**	
DWG NO		**PHOTO C/T NO**	

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SMR 98072 Stone wall

SMR 98072 Stone wall continuing outside the site