ENVIRONMENTAL SERVICES GROUP
REPORT NO. 2391/97

RCHAEOLOGICAL EVALUATION OF SOUTH SITE, WALTHAM ABBEY, ESSEX

FINAL REPORT

BY STEVE CHADDOCK M.A. A.M.A.

BRITISH AEROSPACE
DEFENCE
ROYAL ORDNANCE

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1. CIRCUMSTANCES OF SURVEY

1.1. SITE

The remains of Waltham Abbey Royal Gunpowder Factory extend for over 4km between 19-21m above Ordnance Datum (OD), over sand-and-gravel flood-plain on the east side of the River Lea. A location map is included at Appendix 4.

The east-west cross valley routes divide them in the modern landscape into three. North Site lies north of Highbridge Street, Lower Island Site between Highbridge Street and the M25 and South Site to the south of the M25. This survey is concentrated on South Site alone, although Waltham Abbey Royal Gunpowder Factory was connected through changing manufacturing flow lines both within and between all three sites.

The Royal Commission on the Historic Monuments of England survey of North Site and Lower Island started in January 1993 and the report was completed in December of that year (RCHME 1994).

1.2. SOURCES

Generous co-operation from a number of individuals, local and national bodies during the RCHME fieldwork and report writing, brought to light a wealth of information concerning Waltham Abbey RGPF, which has been considered in this survey. Further material directly related to the Waltham Abbey South Site was found to be stored on South Site by Royal Ordnance.

A catalogue of all sources used and their locations is attached to this report as Appendix 1.

The size of the documentary archive combined with time restraints has restricted the depth of research to evolving an understanding of the site, its processes and development. Explanation of the manufacture of more common explosives and propellants can be found under a section headed 'Technology'.

2. METHODOLOGY

A method had already been developed in principle by RCHME (Cocroft, 1996) for the recording of complex industrial sites and the alterations made in this project

concentrated on using a database to input two distinct types of information that could later be brought together as one 'professional paper'.

2.1. Professional Papers

Information on each building or feature was collected through two channels :

A. Historical Research :

Research into the archives listed for each building or feature. Information such as building name, its chronological development, cartographic depiction, documentary references and historical photography was recorded.

B. Building Recording :

Field surveying of each building or feature was recorded on an individual sheet(s). Information including NGR, dimension, condition, relationships, description and remaining artefacts was recorded.

This process generated two sets of sheets for each building or feature. Utilising the common factor on each sheet, a unique number, the information was fed into a Microsoft Approach database and a completed component sheet for each building or feature was generated.
Structures are referenced by number throughout the description of each area in the final report and reference to these professional papers should be made when a fuller understanding of a particular structure is required.

2.2. Photography

Record photography, black and white together with colour slide, is also referenced on each component sheet by number and black and white contact prints are adhered to the sheet. A copy of the photographic register is included as Appendix 2.

2.3. Computer Aided Design (C.A.D.)

An existing topographical survey of the site was obtained from Engineering Surveys Ltd. This was amended to produce an accurate topographic survey of the site which is presented at 1:1250 on AO size sheets and referred to as Period VIII of Appendix 4.

In addition to this a set of Period Plans are provided, at varying scales, to show stuctures that existed on the site throughout different periods in history.
The Period Plans are linked to the Periods followed throughout the text and reference to the appropriate plan when reading the text should allow a more rapid understanding of the site to be gained by the reader.

2.4. Oral History

Due to the pressing time scale, it was not possible to fully explore the memories of ex-Waltham Abbey personnel, although the small amount of oral history work undertaken on a casual basis proved extremely useful.

3. STATUS AND ORGANISATION OF REPORT

This report is the final report, providing information to satisfy a condition on the planning application to Epping Forest District Council Planning Department (EFDCPD).

Following the production of an archaeological interim report, Essex County Council were better able to understand the remains on the south site and required a further six buildings to be recorded in more detail. These are G403, G431, M351, M349, 486 and SS113. Together with the report by Essex FAG on building N544 these seven building reports complete the most recent survey of the site.

It is a fully analytical report on the Waltham Abbey RGPF South Site and is organised by the following sections:

3.1. Final Report

A written report describing the history of each of the areas on site and considering flowlines of manufacture, connections with North Site, transport, power, safety as well as some explanation of the technology of explosives manufacture. Appendices to the report give the historical sources and their locations, a register of the modern photography and a list of the more important artefacts.

3.2. Professional Papers

A collection of component sheets containing all the collected information on each building or structure. Bound separately from the final report they are divided into groups by geographical area. This is stored on a Microsoft Access database and is available as data on floppy discs. The fields on the database are:

[Artefacts]	Location and brief description of potential museum artefacts.
[Cartographic Depiction]	Referenced historic maps and plans.
[Condition]	General state of structure (good, fair, poor, demolished).

[Description]	Building description as detailed in RCHME methodology.
[Documentary References]	Reference is made to historic documents and other more modern collections of information. A full record of the documents referred to in this section can be found in the Catalogue which forms the Appendix I of this text report.
[Start Date]	For a phase of use.
[End Date]	For a phase of use.
[Name/Function]	Main use of structure in a given period.
[NGR]	National Grid Reference (10 digits)
[Number]	Existing RO numbering system.
[Old Series Number]	Previous RARDE or War Office numbering system.
[SS Number]	Numbering system developed on site in 1996.
[Photography Historic]	Referenced historic photography.
[Photography-WASS]	Modern survey photography with WASS prefix.
[Relationships with other Monuments]	Associated structures listed by number.

3.3. DRAWINGS

Topographical Survey
The 1:1250 overall topographical survey created in a multi-layered Computer Aided Design or C.A.D environment is held as .dfx files and produced as hard copy field sheets (AO size).

Period Plans
A set of explanatory plans of all or part of the site as it existed at different points in time. Presented as Appendix 4 and bound as a separate volume in plastic wallets, a list of the period plans illustrating the final report follows:

Period	Date	Description Heading
I	pre 1887	Ordnance Survey 1st Edition copy
II	1887 - 1890	New NC Factory
III	1890s	New NG Factory
IV	1900 - 1913	Cordite MD factory & Drying Stoves
V	1914 - 1918	1st WW further developments
VI	1919 - 1938	RDX
VII	1939 - 1945	None provided
VIII	1945 - 1991	Survey at 1:1250
VIII A	1945 - 1991	Project 1
VIII B	1945 - 1991	Project 2
VIII C	1945 - 1991	Project 3
VIII D	1945 - 1991	Ballistic Assessment

- The headings given on the Period Plans refer to the Periods I through VIII in the text.
- Lines of railways and canals have been added where necessary from historic maps and plans.
- There is no plan representing Period VII as there were no significant changes made to the site in the Second World War period.
- Projects 1 to 3 and Ballistic Assessment are shown on separate smaller plans and serve to demonstrate how the site was subdivided for research work.

3.4. ACKNOWLEDGEMENTS

Access at short notice was granted by Rebecca Denness at P.R.O Kew and Susan Dalloe at EFDM.
At R.O.F (closed) W.A South Site assistance was given by Graham Vincent, Trevor Wilson, Lynn Lennard and Terry Stemman.
Jill Ball at R.O Summerfield provided relevant documents on explosives processing.
Thanks are due to Bryan Howard, Ron Treadgold and Ken Bascombe for their reminiscences about the site.
Building Recording and Photography were carried out by Essex County Council Field Archaeology Group under the guidance of Stuart Foreman. E.C.C.F.A.G. also amended and manipulated the C.A.D drawings.
Wayne Cocroft of RCHME was retained as recording consultant throughout the project to advise on the recording procedures and interpretation of the monument.
E.C.C Archaeology Advisory Group's Shane Gould and English Heritage's Jo Short and Deborah Priddy monitored works.
Melissa Eyears was relied upon for typing skills and proofreading.
Tim Stevens and Jon Binns were retained as historical research consultants and also had input into this report.
Liaison, co-ordination and report writing by Royal Ordnance's archaeological consultant, Steve Chaddock.

4. INTRODUCTION

The history of the Royal Gunpowder Factory at Waltham Abbey reaches back to the mid 17th century and, over 300 years of activity, it has operated as a manufacturing facility for propellants and explosives as well as a research and development facility. The site is commonly split into three, comprising the North Site, Lower Island Site and South Site. It is the South Site that this report covers as both the North Site and Lower Island Site have been recorded by the Royal Commission on the Historical Monuments of England (RCHME), whose report has been circulated (RCHME 1994).

Following recording work by the RCHME on North Site and the Lower Island, a method for the recording complex industrial landscapes was developed (Cocroft 1996) and, apart from small adjustments, this methodology has been followed in the recording of the remains on South Site.

A huge amount of documentary material relating to South Site is held by various bodies and an understanding of this material was seen as essential to a fuller comprehension of the site as a whole. Consequently, a programme of historical research covering documentary and cartographic material held by Royal Ordnance plc (RO), Epping Forest District Museum (EFDM) and the Public Record Office (PRO) at Kew was undertaken. Due to the constraint on time, the search through this material has been necessarily swift and selective. This report contains a catalogue of the sources consulted during the historical research as Appendix 1.

Many of these documents are held at South Site in the former **Fire Station** [P754], other locations are also listed in the catalogue.

The RCHME Survey of North Site in 1993 provided a central stable understanding of the early history of the site as well as explaining the processes involved in the manufacture of gunpowder and some of the later chemical-based explosives and propellants. It can be seen that Waltham Abbey Royal Gunpowder Factory (RGPF), whilst a manufacturing facility in the true sense, acted as a pilot plant for the manufacture of new propellants and explosives, developed on site and at the Royal Laboratory, Woolwich and successor departments such as the Research Department and the Armament Research Department. Pilot plants were built and the perfected design would then be replicated many times over in purpose built factories elsewhere in the British Isles and abroad.

The final report considers the south site split into geographic areas that evolved throughout its history. Area G lies to the north of the site, Area M covers the land north of Black Ditch to the west of the site and Area N covers the remaining land to the north of Black Ditch in the east. Area P covers the land in the east to the south of Black Ditch and Area R the land in the west to the south of Black Ditch. Structures with an Area letter prefix will be found within that geographic area. Structures that were unnumbered were given a new number with the prefix 'SS' and are found across all areas of the site.

The completed report consists of three elements, all of which rely on each other for full comprehension of the site, they are ;

. Final Report Text - Explanation of Site
. Plans in C.A.D environment - Topographical Survey and Period Plans
. Professional Papers - Bound separately by Area

4.1. A Short History of Waltham Abbey South Site

The development of chemical-based explosives and propellants in the latter part of the 19th century led to a need to expand the existing factory southwards, and it is here that South Site's history starts. The farm land known as Quinton Hill was purchased, complete with Quinton Hill Farm and outbuildings, from the Grundy family in 1887.

1887 - 1890

The first major phase of building on South Site was the construction of a purpose built Guncotton (Nitrocellulose) factory. Prior to 1885, guncotton had been made in the Highbridge Street works on North Site, but the new factory constructed beside Cobbins Brook to the North of Quinton Hill, provided ample room for the layout of necessary process buildings. There was also construction of a proof range where different guns were used to test various charge types and sizes.

1890s

Shortly after the construction of the Guncotton (NC) Factory, a swift change in the British Service standard propellant was made from gunpowder to cordite. Cordite is made from Guncotton and Nitroglycerine. There was already a factory in existence for Guncotton manufacture. Fortuitously, part of Quinton Hill has a slope which could be utilised in the gravity-fed production of nitroglycerine. And so, in 1891, a new Nitroglycerine (NG) plant was constructed on Quinton Hill. Due to the extreme danger involved in NG production, huge square brick traverses were built and surrounded the Nitrating Houses at the top of the hill. Manufacture continued without incident for three years until a disastrous explosion in 1894 destroyed most of the new plant. It is from the inquiry into the explosion at the Nitroglycerine Plant (Sandhurst 1894), that we gain a picture of South Site at this time.

Initially the cordite paste produced was exported after incorporation to Woolwich to be pressed, but by the end of 1891 a self-contained Cordite Mk 1 production facility had been established at Waltham Abbey(Simmons 1963 p55).

1900 - 1913

Following the development and introduction of Cordite MD (MoDified) in 1901, South Site became part of a larger RGPF factory complex, concentrating on the manufacture of Guncotton and the drying and packaging of Cordite processed on North Site. Longer drying time for Cordite MD saw a marked spread of the factory southwards into Cob Mead where new drying stoves were serviced by barges. Simmons attributes the foresight of expanding the cordite works to take over the existing gunpowder buildings on the North Site to a new Superintendent, Col. Ormsby(Simmons 1963 p49)

1914 - 1918

The RGPF Waltham Abbey produced a large amount of Cordite MD for the first World War. Development of a tramway to link South Site with North Site, through the Lower Island Works and under Highbridge Street, was completed at this time.

The whole factory was also connected by rail to the Royal Small Arms Factory(RSAF) at Enfield.

1919 - 1938

Expansion of the factory after World War 1 was limited although developments were made in plant for Guncotton manufacture and later in the manufacturing process of RDX, a high explosive renowned for its use in Barnes Wallis' bouncing bombs. Planned as a pilot plant, the RDX facility was the sole UK producer between 1938 and 1941.

1939 - 1945

Many buildings were probably reused and little damage was done by enemy action. A general trend towards moving the ordnance production facilities to the extreme north and west of the country, to avoid long range bombers, probably resulted in much of the plant being relocated as well. Formal closure of the site as an explosives and propellants factory happened on the 28th July 1945.

1945 - 1991

After 1945, the Waltham Abbey site took on an increased research role, although small amounts of certain explosives were still manufactured. Establishment of a Research and Development facility on the site ensured continued protection of the site from the public and development work on all aspects of propellants and high explosives was carried out. Important among these developments was the 1950s/1960s collaborative venture with the USA on solid rocket propellant systems. The changing titles of the Waltham Abbey site make for a complicated explanation of the last years of the site. Between 30th July 1945 and 1st October 1946 the site operated as the experimental station of the Armament Research Department which was based at Woolwich. For a few months after October 1946 the site was the Chemical Research and Development Department and shortly after this the Chemical Research and Development Establishment, however, to avoid confusion with another research base at Porton Down, Wilts, the site became the Explosives Research and Development Establishment in 1948. The site name changed again in 1977, when the Rocket Propulsion Establishment at Westcott was incorporated and the joint title became the Propellants, Explosives and Rocket Motor Establishment. In 1984 the South site became the property of Royal Ordnance plc and the North site continued under MoD ownership as the Royal Armament Research and Development Establishment. The South site finally closed in 1989. The North site closed in 1991 and has recently been transferred from the MoD to the Waltham Abbey Trust Company, a charity whose purpose is to maintain the site and open it to the public once more.

5. A CHRONOLOGICAL ACCOUNT OF SOUTH SITE

5.1. PERIOD I PRE 1887

Prior to 1884 the land known at Quinton Hill was farmland, with the **Farm** [SS131] and stables situated close to Cobbin's Brook in the north. Between 1884 and 1887, Colonel Noble had been involved in negotiations with the Grundy family of Lancaster, with an intent to buy Quinton Hill on behalf of the War Department. Initially, the family were unwilling to sell, but the War Office threatened compulsory purchase under the Defence Act. On land valued at £5500, the family asked for £8000, only to be flatly refused by the government. By 1887, Noble had brokered a deal securing the purchase of the Quinton Hill for £3622. 5s. 4d. There was some public anger over the closure of a footpath running across the site but eventually this was quashed. The land was purchased for proof ranges and works connected with the manufacture of explosives, construction began on the new Guncotton Factory and was completed in 1888. (PRO Supply 5/362). An early survey [N54 B.03(1888)] of the site showed Quinton **Farm** [SS131] sited beside Cobbins Brook. The farm comprised a farmhouse on the western side of a sub rectangular courtyard with four smaller structures completing the other three sides of the enclosed area. A kitchen garden seems to have existed to the south of this group of farm buildings. The farm was located at G550's present position. A roughly cruciform (20 x 18m) magazine is also shown c. 240m south west of the farm. This magazine is not shown on the later maps and was probably never built. No evidence of the magazine foundations have been located.

5.2. PERIOD II 1887 - 1890

The first phase of construction on South Site was the Guncotton (NC) Factory in Area G, designed to produce pulped and compressed NC in Abel's method. A survey of the North Site dated 1888, showed an inset of the guncotton factory and acid stores, soaking (dipping) tanks, drying and cooling pits. An office and washing house were also shown. It may be that Cobbins Brook was partly navigable at this point. There was certainly a lock at Lower Island that would have allowed access to the lower level of the Old River Lea, but no wharf is shown beside the new factory. Also at this point, a proof range, comprising Gunshed, Stores, Cell and Butt with associated Instrument Room are constructed to the South West of the factory and are mentioned in the Strand Magazine by William Fitzgerald (Vol. IX 1895 pp 317-8).

The Gunshed was served by a tramway which ran due south and, on reaching Black Ditch, west to a wharf on the Old River Lea. Surrounding all the buildings, plantations of willow and alder were kept, presumably coppiced for the manufacture of gunpowder charcoal. Quinton Hill Farm was also still standing in 1888 and may have been used as offices or shifting rooms for the guncotton workers.

The remains of this factory are limited to [G418], the **Big Room**, part of [G431] (eastern part) **Drying and Cooling Pits** and [G407], **Guncotton Magazine**.

The remains of the proof range are represented only by the **Instrument Room** [M329], although the sand bank behind the Butt may be the bank to the south of [M350], although it is likely that this has been somewhat built up with earth to provide a more effective traverse.

Materials and finished produce were transported by barge to a landing stage on the western end of Cobbins Brook, to the north west of the Guncotton Factory. Guncotton would have been exported off site for packing into shells and other munitions (mines, torpedoes) as a high explosive at this date.

5.3. PERIOD III 1890s

The 1890 s saw the construction of Waltham Abbey's first Nitroglycerine (NG) Factory on Quinton Hill, Area N. This was constructed to serve a Cordite MK 1 facility that used dry guncotton from Area G to make the new cordite propellant. Building development was still restricted to the north of Black Ditch. Internally on south Site the communications were improved with the construction of a tramway that served all three active areas (G, M and N). Landing stages on the Old River Lea provided connections with the North Site Canal System.

Following the explosion in 1894, there was a remodelling of the Nitroglycerine Factory on Quinton Hill and it was soon to be superseded by the NG Factory on Edmonsey, North Site (by 1903).

The 1890s were the last years when South Site existed as a separate manufacturing unit for Cordite. The Mk 1 factory remains are different from those cordite facilities that exist on North Site. Guncotton was manufactured, dried, stored, incorporated with NG and mineral jelly, extruded as cordite that was dried, blended and boxed all within the confines of South Site.

5.4. PERIOD IV 1900 - 1913

Three major developments characterise this period of activity on South Site. Firstly, the alteration of the composition of cordite to produce Cordite MD, instead of Cordite Mk 1, necessitated the conversion of existing process buildings, and also the construction of many new ones, mainly south of Black ditch in the form of Tray Stoves. These were used for drying the cordite manufactured on North Site and were served by a canal system which connected to the River Lea and the canals on North Site.

Secondly, the completion of a new NG Factory at Edmonsey meant that all NG requirements for cordite manufacture could be met on North Site. Consequently, the Quinton Hill NG Factory was decommissioned in 1904, and held in reserve, many of its buildings were demolished in 1907-8. The Edmonsey plant continued to use the Nathan-Rintoul process which had first been used at Quinton Hill in 1903.

Around the turn of the century, a new acid factory and concentration plant was built just east of the guncotton factory. This expansion of the area continued in 1905 when the guncotton factory was enlarged, and the Thomson-Thomson displacement method of nitration was introduced. This RGPF innovation greatly reduced the costs of labour, power and raw materials, whilst improving yields of a more stable guncotton by about 170%.

Improvements and extensions to the tramway system were also implemented, and Cobbins Brook was widened.

During the manufacture of Cordite MD, South Site was part of a larger extended factory that was known as the Royal Gunpowder Factory. Guncotton was manufactured in Area G and exported, wet, by barge to the Wet NC Store [1] at the north end of North Site. It was then passed through drying, incorporation (with NG from Edmonsey NG Plant) and extrusion in the Cordite Process buildings on North Site. Eventually, after 1904, it returned by barge to South Site where the Acetone was recovered in [571] **Acetone Recovery Plant**, before it was dried in one of the Cordite Tray Stoves in Area R. Blending, sorting, gauging and boxing all followed on South Site before it was stored in a Magazine to await the results of quality assessment and then transported away to the filling factories.

5.5. PERIOD V 1914 - 1918

The First World War caused the RGPF's workforce to increase massively in size, as the demand for Cordite MD reached mammoth proportions. To cope with the increased production necessary to meet Ministry requirements, the cordite manufacturing facilities were greatly expanded during this period. Twelve new Cordite Tray Stoves and seven new Reel Stoves, along with two Reeling Houses and a Blending House, were constructed south of Black Ditch, to produce Service Cordite of a variety of dimensions and, therefore, functions. To similarly increase the output of guncotton, a new guncotton yarn dying facility was situated in Area M.

All these new constructions were connected by extensions to the tramway system, and in 1916-17, both North Site and South Site, together with Lower Island, were unified by an 18" gauge railway, passing under Highbridge Street, This facilitated the movement of materials between processing areas, particularly of wet guncotton being transported north to the guncotton drying stoves complex on North Site. Exchange sidings near the Acetone Recovery Plant in the south-west corner gave access to the main line near Brimsdown.

5.6. PERIOD VI 1919 - 1938

After the massive production efforts of the First World War, most of the factory was mothballed, particularly the areas of tray stoves which were no longer required to dry the cordite. Most of these probably lay unused, or saw services as stores, some may occasionally have been bought back into use to manufacture small batches for Service or experimental use.

Research in the Guncotton Factory resulted in the patenting of a new potcher for use in the final purification of guncotton. In the 1930 s the 'Bowden-Parsons Tangential Potcher' replaced those that had been in use since the late 19th century, and became standard plant in British explosives factories.

In 1938, a new plant for the development of RDX manufacturing processes was constructed in Area N, it was also involved in TNT from a similar perspective. The technology developed here was later transferred to other government and private ordnance factories.

It is about this time that other areas of the site were being rehabilitated as part of the national re-armament programme that characterised the late 1930s. Previously, most of the factory had remained unused since 1918. There is little new construction, even of a minor nature, dating from the 1918 - 1939 period, with the exception of the RDX plant.

One of the construction projects that did occur was the building of a system of passive air defence measures, including air-raid shelters, pillboxes and observation posts that would be used to shelter personnel and provide a line of land defence and communication in the event of war.

5.7. PASSIVE AIR DEFENCE

In the years leading up to the Second World War the threat of an attack from the air certainly weighed heavily on all the people living in the south and east of England. The site has four distinct types of defence structure that are thought to have been constructed around the start of the war.

Observation Posts : Probably constructed in the years immediately preceding 1939. They were small posts with a reinforced concrete roof that would withstand most near-misses and debris. The reason for these being within the confines of the site points to them acting as an observation of a raid in progress. Linked by a telephone system to the emergency services and factory management, they would be able to relay information on the progress of the air-raid and call for help if necessary. The slit for observation on each side of the building has had a weapon rest hacked out, perhaps the threat of paratroopers landing was also considered.

Refuges : A map dating from c. 1941 shows thirty Refuges constructed on North and South Sites. South Site had ten of these and still retains most of them. Equipped with non-ventilated gas-proofed doors, an air lock for cleansing, twin dry toilets and at least benches for furniture, these refuges were intended to provide a shelter from gas attacks or bombs. Constructed from a Nissen type hut, they were covered in concrete and then this was heaped over with earth, resulting in a well hidden structure that was protected from blast and debris. A document from the

PRO dated 1937, explains that there were three different lengths, 33ft held 25 persons, 56 ft held 50 persons and a 40ft length refuge was designed as a decontamination centre in case of gas attack (PRO Supp/5/984, 1937).

Surface Shelters : A rectangular building with an entrance at each end forming small spurs. These were probably constructed after 1939 in an effort to provide the workers with more shelter.

Pillboxes : Not actually on site, although [SS128] had been located within Area G, these formed a ring of defence around the whole of the North Site, South Site and RSAF Enfield. Much work on these Pillboxes has been done by F. Nash, and a list of relevant pillboxes is given in the catalogue, Appendix 1.

5.8. PERIOD VII 1939 - 1945

The outbreak of World War II in 1939 probably saw many of the buildings resume production, having been mothballed during the inter-war years. The RDX plant, built in 1938, was put into action and until 1942 was the sole producer of RDX for Service use in the UK. The system of air raid shelters and first aid posts came into use as war broke out, and pillboxes provided a perimeter defence around the site. Internal communications were maintained by a number of observation posts. These passive defence measures were allied to larger schemes of active anti-aircraft activity, designed to defend approaches to north-east London, and the Royal Small Arms Factory at Enfield.

In the event, the factory survived relatively unscathed by enemy action. The Luftwaffe were aware of RGPF and had good high level aerial photographs of the site (RCHME). On the 4th October 1940, **Cordite Tray Stove No.15** [R609] was destroyed by a direct hit and was never rebuilt (WASC 1333). The **Wet Pilot Plant House** [N531] was badly damaged by the blast from a V2 rocket, and all its cladding was torn off (Supply 5/435).

Explosives production ceased at the factory in 1945, in favour of newer factories in the west and north of the UK, which were at the extreme range of enemy bombers flying from air fields on the continent.

5.9. PERIOD VIII 1945 - 1991

Waltham Abbey RGPF formally closed on 28th July 1945, to re-open two days later under the aegis of the Ministry of Supply, as the experimental research station of the Armament Research Department (ARD). On the 1st October 1946 it was established as a separate body, the Chemical Research and Development Department (CRDD), employing roughly one-third of ARD's workforce. Its initial remit was to improve RDX production methods, and the RDX area developed in 1938 continued in a research and development role, mainly on a laboratory scale, to improve and refine extant RDX production, along with the other high explosives such as TNT, HNS and NTO. It remained as such until the plant closed.

In 1948, CRDD became the Chemical Research and Development Establishment (CRDE), only to change its name later that year to the Explosives Research and Development Establishment (ERDE), which it remained until 1977. In the same year, the Chemical Engineering Branch was set up, and this became the basis for the three Projects implemented in the 1950s. One of the objectives of the CEB was to develop liquid rocket propellants, but this section was moved to the Rocket Propulsion Establishment, at Westcott in Buckinghamshire in the early 1950s without being fully implemented. Also, a plant was to be set up for the production of picrite (nitroguanidine) for use as a flash suppressant in shell and bomb fillings, and one of the oldest guncotton buildings [G418] was converted to a picrite pilot plant in 1953 so to do.

Project I dealt with the pre-production manufacture of plastic propellants for use in rocket motors, and occupied the southern portion of P Area, mainly reusing old World War I Cordite Reel Stoves with the gradual addition of some purpose-built buildings. One of the products of this research was the Raven motor used in the Skylark rocket, designed for upper atmosphere research.

Project II reused, or built over, buildings from the old cordite and nitroglycerine manufacturing plants in Area N, and in conjunction with the Royal Laboratory at Woolwich, established a Cast-Double-Base Cordite (CDB) rocket motor pilot plant based on American research. Using CDB was an effective method of manufacturing very large double base cordite charges which would be impossible to manufacture using older extrusion techniques.

Project III used the remainder of Area P, and also spread into Areas R and N, for research into Extruded Cordite, and also into Nitrocellulose Tubes (NCT), the preferred American single-base (nitrocellulose) propellant during World War I.

Though only short-term projects in name, the aims of the three projects carried on into the 1960s as part of Explosives Branch. Research was principally into cordite, CDB, plastic propellants and extruded cordite as before, with the addition, in south Area R, of a pilot plant designed to produce up to 300kg of rubbery propellant for use in rocket motors. Other research was carried out into explosive initiators and the degradation of explosives under stress conditions. In keeping with the aims of the plant to produce not only Service weapons, but also propellants for space research vehicles, meteorology etc., ancillary charges were also produced for such things as space vehicle small directional boosters and ejector seat cartridges. The South Site was primarily used for pilot development work, the limited production of small amounts of materials for specific Service usage, and the manufacture of products for field trials. Purpose-built firing points were built to initiate test explosions, and proof stands and laboratories built for the purposes of ballistic assessment. Remote handling techniques that did not require the presence of technicians in explosives facilities were also developed.

At this time, ERDE was the only government establishment researching and developing non-nuclear explosives of every kind. The south of R Area was handed over to the Inter-Services Research Group (ISRG), investigating explosive initiators.

The area of the old Guncotton Factory had become, and would remain, largely dedicated to various theoretical laboratories and service buildings associated with the maintenance of the factory's plant. In the north-west portion of the site, research was carried out into the manufacture of RD Composition 202, a fuse powder, before the area became the undefined Project V in 1960.

By 1971, ERDE had become part of the MOD Procurement Executive and realignment of the sites activities occurred. Propellants I Branch encompassed the area of Projects II and III, and dealt with propellants based upon nitrocellulose and nitric esters, such as nitroglycerine. Pilot manufacture of propellants was carried out for specific new requirements, and processes were developed up to the point when other Royal Ordnance Factories could safely take over manufacture on a larger scale. Projects included combustible cartridge cases (CCC's), mortar and tank ammunition, energetic plasticisers, TAGN for gun propellants, motors for the Swingfire and Vigilant anti-tank missiles, the Giant Viper minefield clearance system, and new methods of non-destructive testing and ballistic and thermochemical assessment.

Propellants II Branch concentrated on pilot-scale manufacture of plastic and rubbery composite propellants, mainly for high performance rocket research, occupying the southern section of Area P that had been Project I. Propellants were developed for use in motors for guided missiles, space and upper atmosphere research, and general Service rockets, including Oystercatcher, Hoopoe, Nuthatch, Serin and Skyflash. Research was also undertaken into the casting of complex shapes and methods of improving burning rates.

An Administration area straddled the boundary between the two branches at the Sewardstone Gate on the eastern fence.

The Explosives Branch researched sensitive initiators, new composite high explosives, the dynamics of detonation, and underwater explosion, among many other projects. The Process Research Branch was concerned with the study, design, installation and maintenance, up to pilot scale, of new chemical and mechanical processes for the production of propellant ingredients and composite materials. The Thermophysical Properties Laboratory became the reference laboratory for the British Calibration Service, providing testing and data standards for the thermal conductivity of solids, liquids and gases. Trends towards remote handling of explosives continued with the Advanced Explosives Research Branch occupying [M343], including the construction of a 5" gauge railway.

In 1977 ERDE and Westcott joined to become the Propellants, Explosives and Rocket Motor Establishment (PERME), and in the early 1980's this was changed to the Royal Armament Research and Development Establishment (RARDE).

In 1984, South Site and Lower Island were privatised, and fell under the control of British Aerospace plc, while North Site remained the property of the Ministry of Defence. The final phase of activity on the site concentrated on the chemistry and physics of energetic materials and propellants, and research into development and application of polymeric and composite materials for use in weapons systems.

In the factories bicentennial year of 1987, plans for the closure of the establishment were announced, and on 30th June 1991 the site was formally closed. Most of the activities and plant were relocated to other Royal Ordnance factories such as Summerfield, and many of the workforce were similarly employed elsewhere within the company. A programme of decontamination was implemented, in order to satisfy the Explosives Inspectorate prior to redevelopment.

5.10. TOPOGRAPHIC CHANGES

During the research and development activities on site, the tramway rails were removed and replaced with roads, the canals were partly allowed to silt up and others were used as dumps for tipping. It is thought that this all happened in the 1960s.

To the west of the site the construction of the Ramney Marsh Flood Relief channel resulted in the demolition of the **Acetone Recovery Plant** area [571] as well as the **Boiler House** [499] complex. It is possible that some World War II air defence measures were also lost to the Flood Relief Channel.

More recently, the construction of the M25 has changed the aspect of the site considerably. Although it passes to the north of the site, its foundations sit on the Lower Island Site and the traverses which formed part of the Lower Island structures had to be levelled to accommodate it.

6. AREA DESCRIPTIONS

6.1. G AREA

6.1.1. Period I PRE 1887

QUINTON FARM

Prior to 1884 the land known at Quinton Hill was farmland, with the farm [SS131] and stables situated close to Cobbin's Brook in the north. Between 1884 - 1887, Colonel Noble had been involved in negotiations with the Grundy family of Lancaster, with an intent to buy Quinton Hill on behalf of the War Department. Initially, the family were unwilling to sell, but the War Office threatened compulsory purchase under the Defence Act. On land valued at £ 5500, the family asked for £ 8000, only to be flatly refused by the government. By 1887, Noble had brokered a deal securing the purchase of the Quinton Hill for £ 3622. 5s. 4d. There was some public anger over the closure of a footpath running across the site but eventually this was quashed. Purchased for proof ranges and works connected with the manufacture of explosives, construction began on the new Guncotton Factory and was completed in 1888. (PRO Supply 5/362).

6.1.2. Period II 1887 - 1890

NEW GUNCOTTON FACTORY

The purpose built factory was built in Area G and is the earliest manufacturing facility on South Site. The early factory was constructed to the west of the **Farm** and **Stables** [SS131, SS137], that were already in existence. Manufacturing Guncotton by Abel's improved 'pulped and moulded' method, a description of the processes involved can be found in the Technology Section on Guncotton **10.1**.

Guncotton Magazine [G407] stood to the west of the main factory area. The factory itself was split into two ranges running east-west. The northern range contained (from west to east), an **Office** [SS155], **Coal Yard** [SS157], **Soaking Tanks** [422] and **Acid Stores** [422a]. The southern range consisted of the **Big Room** [G418], **Drying and Cooling Pits** [G431] as well as the **Cotton Waste Store** [430] at the extreme eastern end of the range. Between the factory and the farmhouse, a **Dining Room** [443] and **Washing House** [442] and **Latrines** [445] were provided for the workers.

Of these early structures, the **Big Room** [G418], and the eastern half of the **Drying and Cooling Pits** [G431] survive after much remodelling over the last 100 years.

6.1.3. Period III 1890s

During the 1890s the tramway system on south site was extended to meet the far western edge of the **Big Room** [G418]. The Guncotton Magazine was demolished and a **Plumber's Shop** [G407] was built in its place. A **Plumber's Office** [SS138] was added to the western facade of the works. To the north of the Plumber's Office a building called the **Tinman's Shop** [G411] was constructed. Generally the layout of the works was similar to the preceding period except that there was an **Acid Separating House** [424] constructed to the east of the **Acid Stores** [422A], and **Air Compressors** [SS136] to the south of the **Big Room** [G418]. A **Police Hut** [SS134] was located just to the north east of the farmhouse and stables. Some buildings changed names at this point, the use of the building is likely to be similar, however. **Washing House** [442] became a Shifting Room, this term is used commonly in later years of the factory but certainly washing may have gone on when "shifting" out of civilian clothes into danger building clothing and vice versa.

The Guncotton works suffered some damage in the 1894 explosion on Quinton Hill, but it was mostly minor and was quickly repaired. Workmen can be seen repairing damaged window panes in the photograph (PRO Supply 5/860/74) taken in 1894 on 7th May. This also shows two of the chimneys for the steam engines which provided power for the beaters and other machinery, as well as heating the water for the boilers and pipes through the drying machines in [G431]. There is also a pipeline shown on a photograph (PRO Supply 5/860/59) taken in 1896, which is probably the return acid pipeline to the **Acid Separating House** [424]. By 1894 the **Nitric Acid Factory** [425] had been built close to the **Denitration House** or **Acid Separating House** [424], the **Chimney** for [425] can be clearly seen on a photograph (Supply 5/860/59) dated 1894.

On the Ordnance Survey 2nd Edition (1897) the layout of the factory was changed only slightly. A **Refrigeration House** [446] is shown in close association with the **Air Compressor** building [SS136]. A **Gasometer** [SS161] was also built around this time and possibly supplied gas for lighting in some of the buildings. Tramways can be seen extending to all parts of Guncotton works on the 1897 O.S. map. The **Coal Yard** [SS157] and **Office** [SS155] do not appear.

From these new additions to the factory, the following buildings survive with all or part of the 1890s building included in their structure : the **Plumber's Shop** [G407], the **Tinman's Shop** [G411], the **Big Room** [G418], the eastern part of the **Drying and Cooling Pits** [G431] and part of the **Refrigeration House** may survive in [G429].

6.1.4. Period IV 1900 - 1914

Following developments in the manufacture of Cordite after the Boer War, there was a corresponding change in the layout of South Site. This change was aimed at ensuring the new Cordite MD could be processed efficiently and there was an expansion of all facilities on site. The main development can be tied down to 1904-5 and is evident in Area G. There is also a change happening in the manufacture of Guncotton. The displacement process, devised by Thomson and Thomson,

remodelled the factory and many existing buildings were re-used in the new process. Despite internal remodelling, some fresh building was also called for.

Developments to the east of the Guncotton Works focused on an acid factory to concentrate and manufacture the Sulphuric and Nitric acids needed for Guncotton manufacture. To the east of the **Nitric Acid Factory** [425], a **Cover for Nitre Cake** [432] was erected, and to its west a **Nitrate of Soda Store** [423], the latter used in nitric acid manufacture by treatment with sulphuric acid, the former a by-product of that manufacture and sold on to the Harpic company. Further east a new **Boiler House** [G440] was constructed in 1904 with Pump House attached, to power the processes in the Nitric Acid Plant and new **Sulphuric Acid Concentration Plant** [435] and **Nitric Acid Concentration Plant** [G443] with a **Tower for Acid Tanks** [437].

Further east again by Quinton Gate, the **Police Hut** [439] moved to the gate and a **Cycle Shed** [438] was provided for workers. There was also a **Gas Meter House** [439A]. Further improvements for an expanded workforce can be seen by the extension of both the **Guncotton Dining Room** [443] and **Shifting Room** [442] in 1903-4.

More facilities were provided to the west of the main range, a large **Boiler House No.7** [419] was built in 1902-3 with **Economisers** [417, 418] and **Chimney** [416]. Coal was brought into the Boiler House from a tramway along Cobbins Brook and hoisted up via a **Coal Elevator** [415]. Such a large Boiler House, with at least fourteen screw fed boilers, would have produced steam for a large part of the site, the **Fan House** [412] built in 1903 would have been driven by that steam as well as the **Power House** [G403] to the west, which produced electricity from steam power. Between these two stood the **Plumber's Shop** [G407], **Earth Closet (E.C.)** [409], **BWD Store** [408] and **Shifting Room** [411].

A **Coal Yard and Engine Room** [420] to the south of the new Boiler House and to the west of the Power House the main **Building Works Department** [BWD] **Yard and Stores** were located [408]. All these new buildings were tied into the rest of the factory by tramway communications. The **Wagon House** [G415] was built at this time between the Gasometer and the Big Room.

To the south of the main range a **Wet Guncotton Packing House** [450], **Hose House** [448], **Motor Spare House** [G424] and two **E.C's** [449, 445] were built around the Refrigerating House and Air Compressors. To the south of the **Packing House** [450], a **Soldering House** [451] was also built in 1902. Further east a large area was given over to the **Acid Storage Tanks** [SS151] and a **Machine Shop** [G432].

Of these new structures in Area G, the following survive in part or whole: **Wagon House** [G415], **Motor Spare House** [G424], **Machinery Shop** [G432] and **Boiler House and Pump House** [G440].

6.1.5. Period V 1914 - 1918

In the first three years of the First World War, nineteen structures were added to Area G. An extension to the **Nitric Acid Concentration Plant** [436A] in 1915. **Vat House** [421A] was constructed and the **N.C Store** [422A] was converted to a **Vat House** as well. The **Press Houses** [421B] and [450A] were also erected, as was a **Box House** [449A]. These were all direct additions to the facilities for processing the Guncotton during 1915 and 1916. In 1914 a **Picric Acid Factory** [425] was built for the production of Lyddite, which was a standard shell filling in the early part of the First World War.

During 1915 and 1916, there was also some expansion in facilities for management and welfare of the Guncotton workers, a large proportion of whom were female in the 1st World War. **Pay Office** [G449], **Guard House** [408A], **Stokers Shifting Room** [412A], **Cycle Shed** [438A], **Ticket Stations** [438B, 444C] and **Shifting Room** [441A], **Petrol Shed** [440], **Smith's Shop** [444B], a **Box House** [449A] and a **Fire Engine and Hose House** [451A]. An extension to the **Dining Room** [443A] was also made at this time.

Fewer developments can be seen in the last two years of the 1st World War. A **Pump House** [419A] was added to the side of the Boiler House. An **Electric Tractor Charging House** [430A] and a **Motor House** [434A] to power a **Nitre Cake Crusher** [434B] were also built in 1917-18. The **Acid Tower** [437A] and **Nitrate of Soda Store** [440C] appear at this time. A **Timekeepers Office** [439C] was built in 1917.

Of all these 1st World War built structures, only **Nitrating House No.2** [G430] and the **Pay Office** [G449] survive to the present day. They were both constructed in 1915.

6.1.6. Period VI 1919 - 1938

Area G in the period between the wars was relatively inactive and no major construction projects were undertaken. In 1923 an extension was made to the **Picric Acid Factory** [425B], the eastern end of [G431] had become known as the **Guncotton Foreman's Office** [431A], previously it had been the Cotton Waste Store No.2, and **Hose House** [448] had changed its use to an Electric Spares House, probably for the **Electric Tractor Charging House** [430A] built in 1917. The **Refrigerating House** [G429] was extended as well in 1928.

6.1.7. Period VII 1939 - 1945

The 2nd World War was, for the majority of South Site, a time of inactivity but Area G contained the main **Boiler House** [419] and the acid concentration facilities for RDX manufacture close by in Area N.

There was a **Pill Box** [SS128] in the north east corner of Area G which formed part of a ring of observation posts around the Royal Gunpowder Factory and it is probable that these would have been occupied during a raid in order to relay

information to the management and emergency fire services. South Site received little damage from enemy action during the Second World War.

A **Water Softening Tank** [G401] and a **Water Softening Plant** [G402] for No.6 Boiler House were constructed in 1942. The hard water at Waltham Abbey had benefited the Guncotton manufacture in the late 19th early 20th centuries, but it was obviously a problem in other uses and lime-scaled boilers would have been very inefficient. A **General Store** [G424] was also built in 1942, and also part of the old **Refrigerating House** [G429] was turned into a Substation in the same year.

All the newly built structures above survived to the present day except for the Pillbox near Quinton Gate which was levelled.

6.1.8. Period VIII 1945 - 1991

In the research and development phase on Area G, a lot of structures were demolished and there was a general remodelling on site. Although most of the demolition happened in 1970's, it is likely that the majority of the remaining plant from the Guncotton Factory was removed in the 1950s. The large **Boiler House** [419] with its economisers, coal elevators and chimney were all removed in the 1970's. A modern **Boiler House** [G405] was constructed in 1966. Almost all of the Acid Concentration and manufacturing facilities, between the Guncotton Factory and Quinton Gate, were dismantled, as was the **Picric Acid Factory** [425]. The **Vat Houses** [422, 422A, 421A] were also removed and built over. Some welfare facilities were also removed, **Dining Room** [408], **Guard House** [408A], **E.C** [409], **Shifting Rooms** [411, 412A] and **Offices** [414] as the factory was turned into a research and development establishment and had different needs.

During the first years as the CRDD, most of Area G was used by a section known as S.C.E who undertook Chemical Engineering experiments for themselves and probably the other departments on site. Reference to Area G component sheets will give a more complete picture of the S.C.E building usage but a short description gives an idea of the activities going on.

Chemical Engineering Laboratory [G421] was in operation between 1959 and 1961, [G418] was given over to the Nitro-Guanidine Pilot Plant between 1953 and 1972. S.C.E. had a **Large Scale Plant** [G430] between 1960 and 1961 before its use changed to experiments with asbestos fibres. A **Milling Facility** [G442] operated as well as a **Tank Farm** [G445] before the building was demolished and later rebuilt as a Drawing Office in 1982. The Chemical Engineering Department (S.C.E) would also have made use of a number of Solvent and Acid and General Stores that were constructed post 1945 [G417, G419, G420, G425, G426, G427, G428, G432, G437]. The **South Site Main Stores** [G431] were in operation from 1959 onwards. The **Police Lodge** [G454] was built in 1962 at the entrance to the works at Quinton Gate, a **Clocking Station** [G450] was built at the same time but was demolished in 1982. It was mentioned that the 1970's saw a great deal of building demolition, this is also a time of fresh construction, although of a more makeshift nature. Prefabricated **Marley Stores** [G422, G423, G446] as well as other **Offices** [G413, G415, G432, G436] were constructed in Area G. The 1959

Chemical Plumbers Office [G408], was an Engineers Workshop between 1962-72, a Chemical Plumbers Workshop between 1972-88, before becoming a Woodstore up to 1990. Many other buildings had similarly chequered careers between 1945 and site closure and most of the remaining buildings are now occupied by short-term tenants as stores and workshops. For example [G411], originally known as the Tinman's Shop, was a Laggers Store and Plumbers Shop before finishing its useful life as a Cycle Repair Shop for Royal Ordnance bicycles up to 1990 (L.Lennard Pers. Comm.).

6.2. M AREA

6.2.1. Period II 1887 - 1890

"The testing armoury and proof range are at Quinton Hill, but are within the boundaries of the factory. It is most interesting to behold the array of field artillery and naval quick-firers, all clean and bright and with a business-like appearance. When the gun is ready to be fired, every person leaves the vicinity; the electric switch is moved in the instrument room some distance away, and with a terrific roar, accentuated by the confined space, the gun hurtles its projectile 17 feet into the sand of the distant butt".

The account reproduced above is from The Strand Magazine, Vol. ix 1895, pp317-318 and is interesting because it describes the activities surrounding the proof range on South Site, as well as directly mentioning the Instrument Room. Of the buildings still surviving, the Instrument room [M329] is the most complete. Built in 1887, allowing remote firing to be carried out, it was a standard part of any proof range. By 1890 it had been extended to the south and was in use as an office, it is still occupied by AutoGear and used as an office/workshop.

Although none of the other proof range buildings survive, the sand bank behind the Butts is retained as part of the traverse to the south of the **Spigot Drop Test Tower** [M350].

The remaining buildings from the 1885-1890s in M Area are; **Experimental Guncotton Stove** [459], **General Store** [468], **Gun Shed** [471], **Cell** [472] and the **Wharf** [SS139]. These have all been removed.

A tramway connected the **Wharf** [SS139] with the **Gun Shed** [471].

6.2.2. Period III 1890s

Most of the new buildings constructed in the 1890s in M Area were built between 1890 and 1895. Only the **Shed** [473] was constructed in the second half of the decade.

The other structures were all part of a Cordite Mk 1 expansion period on site. Facilities to process Guncotton and Cordite are evident. A **Guncotton Drying Stove** [M351] with its **Fan House** [495]. Two **Dry Guncotton Packing Houses** [M347 & 466]. The **Cordite Tray Stove** [M338] with associated **Engine House** [M337]. **Cordite Tray Store** [M352]. **Guncotton Drying Stove** [461] and its **Fan House** [462]. A **Box Store** [M349], a **Cordite Blending House** [M348] and a **Cordite Magazine** [M342] as well as the **Cordite Wharf** [405] at the junction of the Old River Lea and Cobbins Brook.

An expansion of the tramway system during this stage is covered in the tramway section.

It is imagined that the proof range, which existed at this time, was still in use as the **Shed** [473] was added in 1890.

6.2.3. Period IV 1900 - 1913

Elsewhere on South Site during 1903-4, a large expansion in Cordite manufacturing facilities was evident. In M Area this large scale development went largely unnoticed.

Possibly connected to the 1903-4 R Area Cordite Tray Stove scheme, a boiler house complex was constructed in the south west of M Area. This comprised a **Boiler House** [499], **Chimney** [501], **Economiser** [500], **Dynamo House** [498] and **E.C** [497], it is difficult to say whether this complex was intended for electricity supply, steam heating, or perhaps a combination of the two. It is ideally located to supply the steam for heating the Cordite Tray Stoves in R Area immediately to the south. Construction of **Dry Guncotton Magazine** [M326] in 1904 could be seen as an expansion of production, but it is on a more moderate scale than the Cordite MD expansion programme.

A large **Reservoir** [464A] was also constructed at this time, to the west of [M338] **Tray Drying Stove**. It is likely that this reservoir was to maintain a supply of water to the new
G Area **Boiler House No.7** [419].

In the north west corner of the site, and associated with the **Filter Beds** [SS140, SS141], **Pump House** [M317] was also added at this time. Its purpose is unclear.

Of all the buildings constructed in 1900-14, two remain as standing structures, the **Dry Guncotton Magazine** [M326] and the **Pump House** [M317].

6.2.4. Period V 1914 - 1918

During the Great War the greatest number of new buildings constructed were given over to the drying and storage of Guncotton. There were seven **Yarn Drying Stoves** [472A,B,C,D,E,F and G] that were located in the region of [M343] and two **Dry Guncotton Yarn Stores** [405B and 460A]. All these have now been demolished. **Dry Guncotton Packing House** [M347] is still standing.

To the north of the **Reservoir** [464A], a **Pump House** [464B] was built in 1915 and this still remains.

Two **Dining Rooms** were built in 1917 [453A and 498]. The latter was lost in the widening scheme on the Old River Lea and the **Foreman's Dining Room** [453A] has also been demolished.

6.2.5. Period VI 1918 - 1935

The only new addition to M Area is the **Well** [462A] which was dug in 1923. It may have been associated with **Pump House [**M317]. On 15th December 1925, there was an explosion reported in [M326], a **Guncotton Stove** that was being used as a mill for R.D Composition 202 manufacture (PRO Supply 5/334).

6.2.6. Period VII 1939 - 1945

During the Second World War few new buildings were constructed in M Area. The **Tractor Charging and Repair Shop** [M331] was established for recharging batteries from the electric tractors used to haul wagons on site (see Tramway Section).

Two **Air Raid Shelters** or **Refuges**[M344 and M353] were also built to provide some last-minute shelter for process workers. A **Gas Proof Shelter** [SS219] is constructed to the south of [M323].

6.2.7. Period VIII 1945 - 1991

The Research and Development phase in M Area concentrated on Ballistic Assessment and Smoke Trials. Ballistic Assessment facilities, centred on [M343], was used by both Propellants I and Propellants II Branches from the 1960s onwards.

By 1963 it was deemed necessary to erect a facility in which quality charges needed for assessment could be produced in complete safety, regardless of any waywardness which the materials may exhibit. With the Ballistic Assessment Advanced Explosives Remote Processing Facility the Establishment was in a position to do this for a wide range of new compounds, in quantities equivalent to 15lbs of TNT. Here ingredients could be stored in isolation, transported to processing areas, and accurately dispensed, and compositions could be vacuum mixed and moulded, heat-cured in isolated ovens, and inspected, raidiographed, assembled and into test rounds, and fired. The entire sequence was remotely controlled and operators were fully protected and separated from the explosives at all stages. All process operations could be carried out under controlled atmospheres, and samples taken from the process line could be brought into armoured work-cupboards in air-conditioned laboratories where small scale compatibility, sensitiveness and process control work could be carried out.

The facility was built around a massive reinforced concrete emplacement, in which explosives operations were carried out. Control, laboratory, and accommodation areas were wrapped around the stronger front side of this emplacement, and magazines,

curing ovens, and test firing sites were situated beyond a concrete apron at the rear. Transfer of hazardous materials between storage, processing and test points was by a 5-inch gauge electric railway. Services included plenum heating, dry air, compressed air, vacuum and emergency power generation. Manipulators used at various stages included simple tong, master-slave extended reach, and robot types, but dispensing, mixing and filling were carried out by a fully-mechanised remotely-operated unit designed and developed within the Establishment, and housed in a controlled-atmosphere chamber. This would process a wide range of viscous slurries, and incorporates many features designed for the safe handling of sensitive ingredients and mixes.

Smoke Trials, assessing the factors encountered with smoke emitted from solid and liquid propellants, were carried out in the **Firing Point** [M322] and the **Observation Point** [M323], both constructed in 1965.

Further construction in this phase added a range of smaller structures to M Area. In 1952 a **Metal Powder Store** [M332]. Between 1964 and 1966 **Police Hut** [M316], **Expense Magazine** [M321] and **Store** [M330] were built. During the 1970's another **Police Hut** [M315], an **Incinerator** [M319], a **Control Room** [M320], a **Mower Shed** [M327], **Scrap Metal Bins** [M328], **Office Store** [M333] and **Magazine** [M335] were added. In 1980 a **Control Room** [M350], **Spigot Drop Test Tower** [M358] and finally in 1982 a **Store** [M346].

6.3. N AREA

6.3.1. Period III 1890s

Quinton Hill NG Factory came into operation in March 1891 as a direct response to the new realisation that cordite (which requires NG for manufacture) was vastly superior to traditional powders as a propellant. Not only could it produce greater muzzle velocities and project heavier shells, but less grains were required to effect such results. For example, 70 grains of black powder were required to produce in a service rifle a muzzle velocity of 1850 ft/sec., whereas 30 grains of cordite produced a velocity of over 2000 ft/sec. Similarly the use of 4lb of powder in a 12-pounder gun produced less satisfactory results than a 16oz cordite charge in the same weapon (Fitzgerald 1895 : 313-314). In still larger guns, the improved effects of smaller charges of cordite as compared to gunpowder were even more apparent (RCHME 1993:182; Lewes 1915:823). There was also a more obvious benefit to using cordite in place of gunpowder, the lack of smoke on firing does not give away your position to the enemy.

Colonel Noble, RGPF Superintendent, travelled to the Oplagen NG plant in Germany, and returned with recommendations that the German factory be used as a template for a new factory at Waltham Abbey, including the purchase of appropriate plant from the Germans. Mr. McRoberts of the Nobel Factory at Ardeer advised on

certain modification of the Oplagen scheme as had been in place at Ardeer since 1873, and the factory that began operations in 1891 seems to have been a modified version of the Oplagen plant incorporating these suggestions. McRoberts also suggested the name of a Mr J.M. Thomson as an experienced NG foreman from Ardeer. Thomson started on 12th October 1890 with a salary of £400. On receipt of the German plant he found it to be badly damaged in transit and set about rebuilding it, following the methods adopted at Ardeer as closely as possible(Simmons 1963 p.48)

The NG factory was arranged so that the chemicals required in the nitration of glycerine in a nitric/sulphuric acid mix to form NG were mainly moved through the force of gravity (see 1895 War Office : pl. XIV); where this was not possible compressed air pipelines were utilised powered by the **Air Reservoir** [SS150].

NITROGLYCERINE FACTORY March 1891 - May 1894
At the summit of Quinton Hill were the two **Nitrating Houses** [477,476], separated from each other by the large brick and earth traverses which surrounded each building (with the exception of the Acid Separating House and the Wash Water Settling House), above and between the two sat the **Charge House** [N543] from which acids and glycerine ran to each Nitrator. Only one Nitrator was in operation at a given time, allowing maintenance to be carried out in the other without disturbing the nitroglycerine manufacturing process.

Glycerine from **Glycerine Store** [479] and mixed nitric and sulphuric acids came into the Nitrating House via holding tanks in the Charge House. The glycerine was nitrated to produce nitroglycerine, and the waste acids run back north to the **After Separating House** [475]. The acid ran into settling tanks, and any NG present was allowed to collect on the surface before being skimmed of and taken by hand to the **Washing House** [N544]. A complete description of this washing house can be found in the report by Essex Field Archaeology Group(E.C.C.F.A.G. 1996)

After nitration, the dirty NG was run downhill in lead-lined gutters to the **Washing House** [N544], where it was thoroughly washed. The waste wash water went to the **Wash Water Settling House** [507] where any remaining NG was removed. From the settling house waters were run into two **Settling Ponds** [SS147A &B] adjacent to Black Ditch. As all water from the NG process came into this pond, and stray NG sank to the bottom, any potentially hazardous build-up was avoided by exploding the pond weekly using a dynamite charge (Fitzgerald 1895:317). This practice is known as 'popping' and the ponds are therefore known as popping ponds.

The clean NG ran into the **NG Store** [486] where it was held in burettes ready for the making of cordite paste. The procedure at the time was to take wet guncotton from the **Magazine** [474] and dry it in **Guncotton Stove No.1** [485]. From the **Dry Guncotton Store** [N553] the dry guncotton was taken to the **Weighing House** [SS145], where it was weighed and put into rubber bags. These were then taken to the NG Store and a measure of NG poured into each bag. This 'poured-on cotton' was transported to the **Old Mixing House** [SS143] where blending was carried out by hand to produce cordite paste.

This relatively inert product went to one of the four **Incorporating Houses** [511, N567, N568, N572]. Acetone solvent was stored in three **Acetone Stores** [481, 482, 480] and in the **Acetone and General Store** [505], all built in 1892, and was used to incorporate the cordite paste. The incorporated paste was taken the short distance to the **Old Press House** [N562] and in 1893 to **Press House No.2** [514] built in that year.

The cords of cordite produced in this way were processed in different ways according to the diameter produced. The largest cords were taken for drying in either **Cordite Tray Stoves 1 and 3** [SS142, N552] or **Cordite Tray Stove No.2** [N579]. The increased demand for cordite may be reflected in the construction of **Tray Stove No.1** [SS142] in 1891 as part of the original factory, **No.2** [N579] a year later and in early 1894 **No.3** [N552] was added.

The smaller diameters of cordite were taken to the **Reeling House** [N569], where the cords were stranded together to form large 'ropes' which were wound onto reels and dried in the **Cordite Reel Stove** [N554].

MAY 1894 EXPLOSION

In the afternoon of Monday 7th May 1894, an explosion in the Washing House severely damaged the fabric of the factory, halved production, and killed four men in the process. The **Washing House** [N544] and **NG Store** [486] were completely demolished, and most other buildings in the area badly damaged, including Nitrating House No.2, where a nitration was in progress.

The Court of Inquiry (Sandhurst 1894) could not find any definite cause for the explosions, but proposed many suggestions and recommendations, particularly in respect of working practices. A new process for mixing NG and Guncotton was devised, in which NG would not be stored in liquid form, but was washed and poured on to the Guncotton as quickly as possible. The brick-revetted traverses were found to have added debris to the blast, and all new traverses were therefore constructed with earth, as they had been at Ardeer, where several had successfully survived explosions. The **Old Mixing House** [SS143], **Charge House** [N543] and **Weighing House** [SS145] were destroyed in the blast.

1894 - 1903

The framework for the NG Factory remained very similar. Two new Mixing Houses were built, surrounded by circular earth traverses, revetted on the inside with brick. **NG Store** [486] being constructed over the destroyed NG Store, and [N575] a short distance away. A **Cordite Mixing House** [N576] was completed in 1894, having been begun before the explosion. A new **Weighing House** [503] was constructed, and the **Washing House** [N544] and the **Nitrating House** [476] rebuilt in the same locations. After the recommendations of the Sandhurst report had been fully considered, the **NG Store**[486] had its function changed to be a **Mixing House**, thereby ensuring that NG was not allowed to stand for any time in the burettes. A **Junction House** [484] was built to convey NG from the Washing House to the **Mixing Houses** [486, N575].

With the exception of usage changes to **Mixed Material Store No.2** [N553] to **Reel Stove** [N567] and to a **Sorting House** [N568], this is how the factory remained until 1903.

In 1901, a minor explosion occurred in **No.2 Nitrating House** [477], and a resultant change in process to make procedure safer meant that the **After Separating House** [475] became redundant. Plant for the new Nathan-Rintoul (see Nathan & Rintoul 1908) process was installed in **No.1 Nitrating House** [476] and enhanced production in 1903. (A renaming of the Nitrating House at Edmonsey to No.1 Nitrating House led to **No.s 1 and 2 Nitrating Houses** [476,477] being numbered No.s 2 and 3 respectively in 1903).

6.3.2. Period IV 1900 - 1913

1903 - 1904

As had been recommended by the Sandhurst Enquiry, a new NG plant was built at Edmonsey on North Site in 1898, further from Guncotton and Cordite manufacture than at Quinton Hill. Five years later, sufficient NG was being produced from Edmonsey that production at Quinton Hill was seen as unnecessary, and the factory was closed on the 27th August 1903. There was also some concern about the safety of the large numbers of contractors working in the area, involved in the conversion scheme for Cordite MD production. The production of Cordite MD would itself reduce the need for as much NG, containing 30% NG as opposed to 58% in Cordite Mk 1.

The plant was temporarily re-opened from May to December 1904 while new Nathan-Rintoul plant was installed in the Nitrating House at the Edmonsey Plant, using only **No.2 Nitrating House** [476]. This was the last time NG was produced on South Site, as despite increased demand during World War I, the Quinton Hill plant was never recommissioned. **Nitrating House** [477], **Weighing House** [503], **Mud Washing Shed** [506] and **Solvent Store** [505] were all demolished and the bricks re-used (PRO Supply 5/710).

The expansion of manufacturing of Cordite MD in this period is evident in the Quinton Hill area. It becomes part of a larger set-up, instead of being a self-contained processing unit.

Press House No.9 [N563] was built in 1903, adjacent to the **Sorting House** [N562], but most other buildings were modified from Cordite Mk 1 buildings. In keeping with cordite manufacturing, there was **Mixing House No.6** [486], **Packing House** [N570], **Experimental House** [509], and the New Mixing House was converted into the **Principal Foreman's Office**[N576]. One **Tray Stove** [N552] was retained, as was a **Reel Store** [N554] and a **Cordite Magazine** [N500]. Other buildings were used as **Acetone Stores** [481, 482, 511, 514, N480, N567, N569] and **Box Houses** [N568, N572]. A new **Cordite Blending House No.3** (later No.2) [N491] was constructed in 1904.

6.3.3. Period V 1914 - 1918

The 1914-18 War increased demand for Cordite MD and several buildings reverted back to move in process flowlines rather than stores. **Press House No.8** [N562] joined its neighbour **No.9** [N563] and **Press House No.7** [514] came into action. Other usage changes include **Sorting House No.2** [N568], **Incorporating House** [N572],**Crushing House** [511], **Dough Store** [N552], **Picric Acid Magazine** [N553], **Clean Store** [N567] and **Machine Shop** [N569]. An **Expense Magazine** [N579] also saw use as a Paste Store.

6.3.4. Period VI 1918 - 1939

RDX Hill

Unlike other areas of the site Area N saw expansion and development in the pre-war period.

After World War I, the search began for an explosive more powerful than TNT, but of comparable stability and which could be manufactured in large quantities. Investigations at the Research Department, Woolwich, into various substances came out in favour of RDX on the basis of power (being half as powerful again as TNT), stability, sensitiveness, economics, and availability of raw materials. This latter is particularly important as RDX is entirely derived from synthetic compounds (hexamine from methanol and ammonia, nitric acid from ammonia) and did not require any imported material.

First synthesised by Henning in 1899, RDX was initially made by dissolving hexamine in concentrated nitric acid, and the solution crystallised in cold water. Henning thought that the resulting fine white deposit might be useful in the treatment of heart disease.

Cyclonite, more properly known as cyclotrimethylenetrinitramine, became known as RDX because at some stage in its development it should have received an RD (Research Department) number as an explosive substance. As the list was temporarily not available, it was assigned the number 'X' as a temporary measure. This title was made permanent at a later date on the basis that the substance was derived from hexamine.

By the start of World War II, a continuous nitration process had been factory proven and production began at ROF Bridgwater of 150-200 tons a week, using plant built on the original Woolwich designs. The 'Woolwich' or 'nitrolysis' process was used at all ROF's and in the USA during the 1939-1945 war.

Similar plant was built at Waltham Abbey South Site, between the Quinton Hill NG Factory and Quinton Way, and production began in 1939. Originally intended as a pilot production unit manufacturing about ten tons a week, research was also carried out into the purification of RDX, the recovery and concentration of nitric acid used in the nitration of hexamine, and the processing of RDX for use in RDX/TNT compounds, plastic explosives, Oiled RDX and so forth.

Hexamine was introduced into one of the two **Nitrating Houses** [N529, N530] and then nitrolysed with concentrated nitric acid from [G448], to produce RDX in

suspension. Waste gases (nitrous acids) were directed away to absorption towers and recovered as 55% nitric acid. The RDX was washed with cold water and then passed to the **Boiling and Milling House** [N534] to reduce acidity, or to crystallise the RDX, so that it became both usable and transportable. RDX was stored in a **Magazine** [N532].

Outside of this main production area were three research areas. A **Wet Pilot Plant House** [N531], a **Small Scale Plant and Processing area** [N535, N536] and another **Small Scale Plant** complex [N537, N539] with its own **Vacuum Plant Room** [N538] situated between the two buildings.

The **Wet Pilot Plant House** [N531], was probably used to wet-mix RDX with TNT, or with various waxes and oils to maximise stability, and then pelleted by cooling the hot suspension whilst stirring rapidly. The oily substances required were supplied by the **Oil Preparation House** [N527]. RDX/TNT was then dried in the **Drying House** [N540] in molten form and cast as slabs. The **Drying House** was built over the old **Glycerine Store** [479] which had served the Quinton Hill NG Factory. RDX was too sensitive to be used in its pure form as a filling in shells etc., and the addition of waxy substances as 'desensitisers' decreased its sensitivity. Until at least 1972, RDX/TNT [1% desenstiser] was the preferred poured filling for many shells and warheads, mainly due to its superior explosive properties. RDX/TNT IB is a 60/40 RDX/TNT including 0.25% of Terylene fibres reinforcing the explosive against shock stresses.

RDX also contributed to the composition of Torpex, a highly powerful underwater explosive, consisting of RDX,TNT and aluminium powder (RCHME 1993:164).

6.3.5. Period VII 1939 - 1945

The plant that had probably lain idle for much of the inter-war period was now brought back into production as demand for explosives once again increased. All the existing buildings were used as per their previous functions for the production of cordite.

At the beginning of the war, a large number of purpose-built air raid shelters were constructed all over the RGPF, and several were built in Area N. Along the northern edge of the Quinton Hill area **Air Raid Shelters** [N504, N510, SS159 (cf. N555)] were built in 1939, and demolished in September 1967. In the south-west corner were **Air Raid Shelters** [N517] and [N516] which also doubled as a **First Aid and Cleansing Centre**. Between these two positions, now occupied by newer buildings, was a brick **Observation Post** [N586] which still stands, near to Black Ditch Road before it turns north into Centre Way. **Air Raid Shelter** [N561] was probably just south of [N550] and was demolished in 1977. **Air Raid Shelters** [N573 and N577] were just north of Black Ditch and the former is still standing. No similar structures

from this period have been detected along the eastern perimeter of Area N, or indeed of Area P to the south.

Some measure of the degree of activity taking place, and the numbers of personnel involved can be seen in the relatively high number of air raid shelters constructed in this area.
Although the South site at Waltham Abbey survived relatively unscathed by enemy action during World War II, the Wet Pilot Plant House [N531] was badly damaged by the blast from a V2 rocket, and all its cladding was torn off (Supply 5/435).

The centre of this activity was undoubtedly the RDX area to the north-east of the Quinton Hill area. Actual production of RDX and other high explosives ceased by the end of the Second World War and work began researching high explosives on laboratory and small scale projects in the RDX area. **Drying and Sieving House**[SS158] was built in 1939 and demolished in August 1969. This hitherto undeveloped area became the centre of RDX production in the UK and is dealt with in 6.3.4 above. The construction of the axial RDX road may have necessitated the demolition of **Cotton Waste Store No.4** [440b] and **Nitrate of Soda Store** [440c], either side of the junction of RDX Road and Quinton Way.

6.3.6. Period VIII 1945 - 1991

RDX

From large scale production RDX, emphasis shifted in 1945/46 to research into improving RDX production methods, and also into other high explosives.

During the continuous nitration filtration of the Woolwich process for production of RDX, it was noticed that unusually shaped crystals adhered to the surface of the continuous filter. On analysis, this substance possessed the same composition as RDX but its molecular weight was 30% greater, hence it being dubbed HMX (High Molecular-weight X). In the Woolwich Process, about 0.1% of the high explosive RDX was HMX. In the American Bachmann process (involving the reaction of formaldehyde with ammonium nitrate) this percentage was approximately 5-10%. Further investigation revealed that the velocity of detonation of HMX was higher than for RDX, and this, coupled with its higher density, made HMX more desirable than RDX for certain purposes. Modifications were made to the Bachmann process to make HMX the principal product. Work was carried out at ERDE in buildings [N535, N536, N538, N539] until 1955, after which production began. It seems that **Nitrating Houses** [N529] and [N530] were used as such throughout the post-war period, and for the manufacture of various high explosives, including HMX, TATB and 'K-Liquid'. TATB (1:3:5 - Triamino - 2:4:6 Trinitrobenzene) was used as a filling for long distance missiles, in which the filling needed to be as resistant as possible to high temperatures. While less sensitive than TNT, TATB (similar to DATB, 1:3 Diamino - 2:4:6-Trinitrohenzene) is more powerful, and has excellent stability in high thermal conditions. 'K-Liquid' is a pseudonym covering various nitrated ethyl benzenes, high explosives of a similar nature to HNS, which is usually found mixed with TNT. Processing of NEB's was carried out in the **Explosive Processing Building** [N514], built over the old **Nitrating House** [476] which was demolished in 1980. The 1983 construction date for this building and its **Monitoring House**

[N521], suggests a 1983-1989 date for research into nitrated ethyl benzenes. **Nitrating House** [N529] was demolished in 1977 and a **Store** [N529] was built in its place in 1980 and another to the west in 1981 [N527]. This latter was built over the old **Oil Preparation House**, which had been demolished in August 1969. Two **Acid Stores** [N522, N523] were built in 1979 and another in 1982 [N525] to supply nitrating operations. A **Waste Acid Store** [N526] was built near [N530] in 1980 to store waste acids from nitration processes. **Nitrating House** [N530] was in operation until 1989. A **Control Room** [N528] for [N530] was built in 1986, but in January 1989 both were devastated by an explosion in a 100 gallon glassed-steel nitration vessel in which 35kg of TO [triazolone] was being nitrated with 210 kg of 70% nitric acid to make the secondary high explosive nitrotriazolone (NTO). The building was rendered unusable and consequently demolished (BF001, 1989).

[N531] was licenced as a 10kg **Nitro-cellulose Nitration Facility**, but this was never installed, and became a **Non-Explosive Store**. The **Magazine** [N532] continued as a 200kg storage facility for most types of high explosives.

Control Room [N533] continued as such for [N534] in its capacity as a **TNT and HNS Pilot Plant**, and the latter was used as an **Experimental Laboratory** for high explosives and hazardous chemicals until its closure in 1990. The **Micronising House** [N535] was involved in a number of short-term processes, most likely related to small-scale experimental milling and grinding techniques for high explosives, probably in attempts to increase explosives purity. **Experimental Small Scale Plant Houses** [N536, N537, N539], the latter two still served by the **Plant Room** [N538], were involved with experimental processing of various high explosives. [N537] may have been a **Perchlorate Store** during the 1970's (WASC 1506/1) and this suggests research into plastic explosives. The same source labels [N539] as a **Polymer Bay** so this does seem likely for a period.

The **Explosive Drying Plant** [N540] was split in two at some point, probably in the mid 1950's, the eastern end continuing as a high explosives drying area (Schultz O'Neill Mill), for all those HE's mentioned in this section, and the western end becoming a **Box and Tray Store**.

PROJECT II

In 1952 Project II began, once the relevant plant was constructed, to develop and manufacture cast-double-base propellants (CDB's). During World War II it had been realised that the increasing demand for rocket propellant charges could not in future solely be met using the existing solventless cordite technique. The requirement for larger charges than could be produced using conventional pressing and extrusion methods led to initial testing in the USA, and in 1947 testing on a laboratory scale began at the Royal Arsenal, Woolwich. The materials under consideration were termed cast-double-base propellants because they contained two explosive "bases", nitrocellulose and nitroglycerine, which were mixed to form a porridge-like mass, and "cast" by pouring into a mould and allowed to set. This method could produce large rocket charges; at Waltham Abbey the experimental

production plant could produce charges up to 2300 lb. in weight, 24 inches in diameter, and up to 9 feet in length.

The basic components of CDB's are a casting powder, a casting liquid, and restrictive container. The casting ingredients were poured into the latter, which became the outer coating of the charge, and allowed even burning rates to be achieved on large charges.

The nitroglycerine required for the casting liquid was extracted from dynamite in the **Nitroglycerine Extraction House** [N557], with its associated **Plant Room** [N558], both purpose-built buildings constructed in 1952. Here it was mixed with a desensitising agent (plasticiser) such as triacetin, and a stabiliser, such as carbamite. The desensitised nitroglycerine casting liquid was then transported to the **Casting Liquid Magazine** [N579] built in 1952. Any water containing nitroglycerine produced by the extraction process was run to the **Wash Water Settling House** [N574], built in 1952 over the original building [507] which performed the same function in the original Quinton Hill Nitroglycerine Factory. Its **Calorifier Room** [N590] was also constructed at this time. Any recovered nitroglycerine was returned to the extraction house for mixing.

The cordite needed to produce the nitroglycerine was stored in the **Cordite Store** [N554] built in 1950 over an old Reel Stove [489]. A **Waste Cordite Magazine** [N581] was built in 1958.

It is uncertain where the casting powder, consisting usually of nitrocellulose, plasticiser, stabiliser and platoniser was manufactured, though it may have been transported from elsewhere. By 1958 it was being stored in the **Casting Powder Magazine** [N554], previously the Cordite Store.

The restrictive containers which would form the outer surface of the cast charges were initially made from extruded cellulose acetate, though tests were also conducted using ethyl cellulose and other similar materials. At Waltham Abbey, they were made in the **Cellulose Acetate (CA) Container Factory** [N563] adjacent to the **Store, Central Laboratory and Office** [N562].

To allow the casting of the charge, a mould had to be produced into which the cellulose acetate tube could be fitted, and the casting powder and liquid introduced. The **Assembly, Charge Filling and Dismantling House** [N550] fulfilled this role, built in 1952 with its **Calorifier Room** [N589]. It consisted of three large high bays, the height being necessary to house the moulds required to fashion the longer rocket charges. The entrance to each bay faced in a different direction as a safety precaution. The central bay was involved in the assembly of the moulds, including the insertion of the cellulose acetate tubes. Another bay was used to fill the moulds with casting powder trucked from the magazine. The third bay will be discussed shortly.

The charge assembly was trucked to the **Casting House** [N556] supplied by its **Calorifier Room** [N587], both built in 1952. Casting liquid was run in a lead-lined gutter from the **Store** [N579], and drawn up through the charge by means of

vacuum, thereby filling all the interstices in the casting powder. The charges were then conveyed in an upright position to the **Curing House** [N553], converted from a Picric Acid Magazine, where the charges were cured in temperatures of 45-60°, allowing the charge constituents to consolidate. Once cured, the charges were taken to the third bay of [N550], where the mould constituents were removed, cleansed and returned to the central assembly bay.

As the ends of the charges tended to be gelatinous and of uncertain composition, they were trimmed in the **Charge Trimming and Inspection House** [N569]. A further slice was removed for inspection. Both qualitative and quantitative inspection methods were utilised to ensure accurate dimensions, burning rates, uniformity, chemical composition etc. X-ray inspection was carried out in [N569], and gamma-ray testing in the **Gamma-Ray Inspection House** [N572]. Ultrasonic techniques had superseded the latter by 1959, when [N572] was converted to a **Small-scale Filling and Ultrasonics Laboratory**. Once passed by inspection, the charges were transported to the **Charge Magazine** [N547].

Other buildings involved with the manufacture of CDB's in Project II include a **Loading Bay** [N546], and a **Truck Charging Station** [N564], which was converted from the old Boiler House [572] in 1950. A **Small-scale Laboratory** [N567] was converted from the old Incorporating House No.2 in 1952, and a **Non-Explosive Store** [N568] from Sorting House No.2 in the same year. A building [N586] of unknown function was also built at the same time, as was a **Lavatory** [N566]. A **Single-Locker Magazine** [N584] was added in 1956, and another **Lavatory** [N580] in 1958.

6.3.7. Period VIII Final Developments

There was a significant amount of activity in Area N during the post-war years, as research and development continued into explosives and propellants.

On the northern edge of the area, along Quinton Way, four buildings were erected in the 1950s for the Chemical Engineering Section (SCE). A **Chemistry Laboratory** [N500a], **SCE Store** [N501], and **SCE Offices** [N502] were all demolished in a phase of demolition during September 1967. The **SCE Offices** [N505] were built in 1959 and converted to **Offices, Typing Pool and Telephone Exchange** by the time of closure. The **Laundry** [N506] built during the 1950s was demolished in September 1969, and built over in 1977 as the **Propellants II Branch Laboratory and Offices**. Other 1950s buildings demolished at this time included a **Domestic Plumbers' Shop** [N512] and a **Lime Shed** [N515], later built over as a **Truck Shed** in 1980. A 1950s **Store and Office** [N511] was converted to a **Plumbers and Wood Shed** but also demolished. Older pre-war buildings demolished include a **Store** [N507], **Women's WC.** [N508], another **Lavatory** [N503], and two **Air Raid Shelters** [N504 and N510]. The **Building Works Department Carpenters and Machine Shop** [N513] built in 1941 became a **Laboratory and Offices** by 1970, and was later a **Plant Store, Small-scale and Chemical Store**, and finally a **Fitters Store**. The **Canteen** [N509] was extended in 1958. At Quinton Gate, a **Gas Meter House** [N524] was built in 1960.

The **Cordite Magazine** [N500] had been demolished at some point but was rebuilt as a **Magazine** in 1982, though on a somewhat smaller scale. [N545] was demolished in July 1977, but rebuilt as a **Magazine** again in 1981. Another **Magazine** [N547] was in use by 1972.

As regards services, a **Reservoir** [N551] and **Pump House** [N552] were constructed in 1970, the latter being built over a **Store** which had been demolished in August 1969. The **Water Tower** [N541] from the old nitroglycerine factory was demolished in June 1979, and the associated **Reservoir** went out of use at about the same time. **Electric Sub-station** [N582] was bought into service in 1954.

There were also several minor buildings constructed in this period. A **Compressor House** [N565] was added to [N567] which had become an **Experimental Processing and Laboratory** in 1978. The **Casting House** [N556] had been converted to **Charge Assembly and Filling** in about 1965, when a **Cook-off Oven** [N558] was added. [N556] was devoted to **Experimental Processing** in 1976 when [N558] was converted to a **Compressor Room**.

Cast-double-base propellant continued until about 1978, when [N562], which had been converted to an **Experimental Casting Laboratory** became the **Energetic Materials Offices and Laboratory**. The adjoining building became offices at the same time, having previously been converted to an **Oven Room and Winding House** [N563]. This is indicative of the process change for manufacturing cellulose acetate containers for CDB charges, in that they were wound into shape using cellulose acetate "foil" rather than extruded. The old **Truck Charging Station** [N564] had partly been modified in about 1969 to include a **Tube Preparation Annexe**, connected with the production of cellulose acetate containers. This building also later included a photographic unit. The nearby [N572] was converted in the late 1960s to an **Experimental Processing House**.

Building [N550], which had been key in the production of cast-double-base propellants, was converted to a **Plastic Propellant Plant** in 1959, and in 1963 a **Control Room** [N571] was added. This building seems to have been instrumental in the development of the propellant for Blue Water, a surface-to-surface missile, when it was also producing polyurethane. By 1972, it was a **Carboxyterminatedpolybutadiene (CTPB) Propellant Plant**, supported by [N554] which was converted to a **CTPB Propellant Preparation Room and Ovens House**. [N550]'s **Calorifier Room** was converted to a **Store Room** at this time.

The **Nitroglycerine Extraction House** [N557] remained as such until closure, but other nitric esters were probably also processed there during the 1970's. A **Refrigeration House for Nitric Esters** [N585] was built adjacent to it in 1970, and an **Acidmix House for Nitric Esters** [N583] in 1977.

Air Raid Shelter No.28 [N573] was converted to a **Non-Standard Propellants Store** in about 1960, as was **Observation Post No.20** [N586] in the 1970's.

Most of the recent buildings erected were pre-fabricated Marley structures. Three **Marley Multiple Garages** [N516, N517 and N518] were put up in 1980. A **Marley**

Flamestore [N520] for the storing of solvents was erected near to the **Energetic Materials Building** [N562]. In 1979 three **Marley Flamestores** [N559, N560 and N561] were put up adjacent to [N550] in 1981, to store the isocyanate adhesive used in fixing CTPB propellant charges into rocket motors.

Most of the buildings in Area P were part of Propellants I Branch, formed in about 1970, for research and development of propellants based upon nitroglycerine and nitrocellulose, i.e. double-base propellants. The long-term stability of explosives was also researched. Products of this research include the anti-tank missiles Swingfire and Vigilant, and the Giant Viper minefield clearance system.
When the establishment became the Royal Armament Research and Development Establishment (RARDE) in the early 1980's, the research emphasis also included work on energetic materials, while work also continued on propellants.

6.4. P AREA

6.4.1. Period IV 1900 - 1913

The expansion of the RGPF during 1903 - 4 for manufacture of Cordite MD meant that the area south of Black Ditch known as Cob Field, was utilised for the first time. Construction centred on a series of structures where the blending, storage and packaging of the cordite could be carried out. **Blending House No.5** [P710] was built in 1903 with its attendant **Motor House** [545B] and **Cordite Magazines No.s 3, 4 and 5** (later 2, 3 and 4, 1907-9) [P712, 563, 564] in 1903-4. They, together with **Packing House No.3** [R601] and **Blending House No.4** [R614] to the west, **Blending Houses No.s 2 and 3** [M348, N491] and **Cordite Magazine No.2** [N474] to the north, formed the end buildings of a cordite manufacturing process that began far to the north of Edmonsey. All the buildings would have been kept at a regular temperature and in the magazines the finished cordite would have remained until results from the laboratory cleared the way for it to leave site for the filling factories.

6.4.2. Period V 1914 - 1918

The Great War of 1914-18 generated massive demand for rifle-sized charges for infantry use, and this is reflected in the development of P Area, in particular during this period, which in terms of construction spanned 1915-17.

Blending House No.5 [P710] was joined by **Blending House No.6** [P715] and **Cordite Magazine No.s 2, 3 and 4** [P712, P714, P716] remained unaltered. The principal demand for small diameter cordite for small-arms charges can be seen in the massive construction undertaken and dedicated to the production of needed cordite strands. **Reeling Houses No.1 and 2** [P705, P704] carried out the actual stranding of the cordite, before it was dried in one of **Cordite Reel Stoves No.s 3-10** [P703, P717, P718, P724, P723, P721, P720, P719].

Both the pressing need to begin manufacture, and the necessity that it both continue and expand, is shown in that **Reel Stoves No.3, 4 and 5** [P703, P717, P718] were built in 1915, **No.s 9 and 10** [P720, P719] in 1916, and **Reel Stoves No.s 6, 7 and 8** [P724, P723, P721] in 1917, expanding to cover what was left of Cob Field. A **Box House** [P708] and **Cordite Testing House** [P706] were built in 1915, and **Women's Shifting and Dining Room** [607] at a similar time.

A new Quinton Gate entrance was opened on the east side of Cob Field sometime during this period, opening out on to Sewardstone Road A112, consisting of a **Police Hut** [606] and **Cycle Shed** [606A]. Between **Blending Houses No.3 and 4** [P614, P710], A **Traffic Controllers Office** [P711] was built on an artificial mound in 1917. Overgrown now, it is furnished with a signal extending from the roof with which the controller directed the drivers of trucks carrying cordite between the processing houses and the magazines, as the drivers would have been unsighted in the traversed landscape.

6.4.3. Period VI 1919 - 1938

There are no recorded changes of building usage between the two World Wars and the Cordite production facilities, even if they were in operation, would have been doing so on a much reduced scale. Buildings constructed during this period were a **Police Hut** [606] and **Cycle Shed** [606a], and a **Hose House** [621]. Three **Observation posts** [P722a, P722b, and P722c] constructed along the southern perimeter fence were provided to allow a watch to be maintained over the site during a coming air-raid.

6.4.4. Period VII 1939 - 1945

There seems to be no change in building usage during the Second World War period in Area P. It is imagined that the plant comes back into operation within the buildings but this is difficult to prove. Some plant may have been removed at this stage to furnish the new factories to the north and west of the country.
An **Air Raid Shelter** [P722] was the only new construction, built towards the north of Area P. All four structures are still standing.

6.4.5. Period VIII 1945 - 1991

GENERAL

During its use as part of the post-war Explosives Research and Development Establishment, Area P was fairly consistently split in terms of function. The northern area, initially part of Project III, continued to research cordite as part of the Propellants I Branch which came into being in the 1970's. The southern area which was Project I maintained research into composite propellants as part of Propellants II Branch. After the initial reuse of older buildings and new construction during the 1950s, no major construction projects were initiated in the area.

Presumably due to the change from canal to road transport and the increased road traffic of goods and people in the 1950s, a new entrance to the site was opened adjacent to Sewardstone Road on the north-east periphery of Area P. This

necessitated the construction of a **Police Lodge** [P746] and **Search Hut** [P747] in 1956, the latter becoming a store some time later. Adjacent to these, a **Fire Station** [P754] had been built in 1954, the same year as the **South Site Surgery** [P748]. A **Store** [P779] was annexed to the fire station in the form of a Portacabin in 1985.

Electrical Sub-stations Nos. 2 & 3 [P751 and P752] began to relay electricity around this area in 1954, and a third [P780] was added in 1988. A **Pump House** [P707] was installed in 1958.

Two other late additions include a **Women's Shift Room** [P700], a Portacabin erected in 1980, and a **Greenhouse** [P777] put up adjacent to the fire station in 1983.

There is only one major documented change of usage in the whole area, that of the MOD Police taking over the old **Cordite Offices** [P743] at some point in the 1970's.

All other modifications and additions can be directly linked to the manufacturing processes taking place in the area.

PROJECT I

In 1956, Area P underwent a rapid program of modifications and regeneration in its southern portion, as research began into the relatively new field of plastic propellants. As cordite became increasingly unsuitable for many military applications, especially as a propellant for large rocket motors, so it became important to develop better materials to overcome the problems of using cordite. One approach was to case-bond the charges, i.e. cement them into rocket motor tube, but there were many early problems associated with attempts to do this. The Explosives Research and Development Establishment at Waltham Abbey became involved in trying to develop a propellant with properties of a similarly plastic nature to the adhesive used in the case-bonding experiments.

The potential advantages of such a "plastic propellant" were many, including the use of different raw materials from cordite, which would be more readily available and cheaper, especially during a war. The presses required to make plastic propellants were cheaper and lighter, and could produce larger sizes of charge. The relative chemical instability of cordite would be avoided and the new propellants had a potentially higher performance level than did cordite.

Whereas in colloidal propellants such as cordite and CDB's, the bulk of the propellant is a nitric ester like nitroglycerine, in composite propellants like plastic and rubbery, the ingredients are chemically separate. In plastic propellants this takes the form of solid oxidant particles in a liquid fuel medium to give a material with a high degree of plasticity. The oxidant is usually a substance like ammonium perchlorate, and the fuel a binding agent like polyisobutene (PIB).

It is uncertain whether ammonium perchlorate was manufactured on site or whether it was supplied by a contractor. It is known that it was dried in the **Ammonium**

Perchlorate Ovens [P728] prior to being ground down into a smaller particle size in the milling bays in the **Incorporating House** [P723]. It was here that the ammonium perchlorate and the polyisobutene were incorporated, along with a coolant such as ammonium picrate, and catalysts such as titanium dioxide. This building, like several other Project I buildings was converted from an older World War I cordite reel stove.

The perchlorate, binder and other ingredients were mixed for about two hours, then de-aerated by passing it through a pugmill. This machine forced the plastic through a multi-holed die at the end of which was a blade which continuously cut the extruded and de-aerated propellant into short lengths. These short cords were then re-consolidated and passed through another die and extruded again as a tube, to be cut into lengths suitable for rocket motors. This process was carried out in one of the two **Plastic Propellant Press and Pugmills** [P729 and P724], the latter being converted from Cordite Reel Stove No.6.

The rocket tubes for filling were checked and thoroughly degreased in the **Plastic Propellant Store and Degreasing House** [P719] before being sprayed internally with the adhesive which would bind the plastic propellant to the internal surface of the rocket motor. The lengths of propellant from the pugmill were fed into the rocket tubes and end-rings fitted, the inside faces of which had also been sprayed with a coat of adhesive.
The tubes containing the loose charges were then put into a hydraulic press which, by using a vacuum and a shaped axial former, filled the inside of the rocket motor with the propellant and provided a burning surface on the inside of the charge. The propellant adhered to the walls of the motor, the former was withdrawn and the charge was ready for inspection.

The charges were inspected for structural abnormalities, etc., in the **Control Laboratory** [P757], and for resistance to thermal stress in the **Hot and Cold Chambers** [P727]. The ballistic properties of the plastic propellant in question were ascertained either in the **Fire Control and Plastic Propellant Testing Building** [P721] and the **K-round Firings** [P753], (K-rounds were miniature rockets filled with plastic propellants and used for static firings during ballistic assessment), or outside on the **Plastic Propellant Proof Stand** [P725] and **Motor Room** [P726].

Other buildings associated with Project I include a **Small-scale Manufactory** [P720], converted from Cordite Reel Stove No.9. A **Solvent Store** [P764] probably supplied trichloroethylene for the degreasing of the rocket tubes. A **Shift House** [P750] was purpose-built in 1955 to serve the staff of the 'Plastics Group'. A six-bay **Locker Magazine** [P755] was probably used to store plastic propellants prior to K-round testing.

PROJECT III - SMALL-SCALE AREA

Due to the secret nature of the research carried out in most of this area it has been difficult to ascertain what was being undertaken in most of the structures in P Area. One small area is, however, reasonably well understood. In the centre of the

Project III area are a self-contained group of buildings, built in 1958 for the purpose of research into cordite processes on a small-scale.

The **Nitroglycerine Extraction House** [P733] produced Nitrogylcerine, probably derived from dynamite, though its source is unclear. The nitroglycerine was mixed with nitrocellulose in the **Wet Mixing House** [P732], and then incorporated in the **Incorporating House** [P715]. The cordite paste was then taken to the **Press House** [P738[to be extruded in the required fashion. The cordite was then dried in either the **Cordite Stove** [P736] or the **Isolation Stove** [P737]. The finished cordite was presumably stored in the **Explosive Store** [P735] or taken elsewhere and used. Alternatively, it may have in part supplied the Nitroglycerine Extraction House. The purpose of the **Weighing House** [P734] is unclear, though the fact that it occupies an intermediary position between the Nitroglycerine Extraction House and the Explosive Store, and is joined to both by a corridor suggests either that NG was being weighed and stored in the building or that cordite was being weighed here. It is also possible that nitrocellulose was weighed here before going to the Wet Mixing House, though it is more likely to have come ready-weighed and bagged.

The small-scale area was served by **Offices** [P730] and a **Boot Porch and Store** [P731].

Buildings [P732-P736] were involved with the small-scale production of cast-double-base propellants by the time the establishment was decommissioned, but [P715, P737 and P738] have unspecified small-scale functions.

FINAL DEVELOPMENTS

The area that was Project I became part of the Propellants II Branch and the area that was Project III became part of Propellants I Branch for the most part. Apart from the changes already described, a few additions were made to the building list of the area.
A **Polymer Store** [P702] was added behind the **Cordite Inspection House** [P704] in 1971, but went on to become a **Small Propellant Store**. A **Locker Magazine** [P769] was erected between the **Sample Store** [P703] and Black Ditch in 1979, and another [P773] close to the **Polymer Store** [P702] in 1980. Two **Marley Flamestores** for storing solvents were erected in 1981/2, one [P775] opposite the laboratory building [P742], the other [P781] within the traverse of the **Horizontal Press House** [P716]. A **Truck Shed** [P771] was built next to the **Sample Store** [P708] in 1982, and later converted to a **Store**. A **Compressor Shed** [P776] was built for the **Quinan Stove** [P740] in 1983. An **Explosives Store** [P756] capable of holding 500 lb. of polyurethane was built for the **Small-scale CTPB Propellant Plant** [P758] in 1965, and was later designated a **Small Magazine**. A **Propellant Sample Locker** [P765] was built in 1974, and a **Marley Flamestore** [P764] replaced the previous solvent store, both for the **Tube Preparation, etc.** building [P719]. Another **Propellant Sample Locker** [P766] was built in 1974 for the **Sample Laboratory and Offices** [P757]. **Magazine** [P770] was erected in 1979, and another [P774] in 1982 by the **Plastic Propellant Press and Pugmill** [P724 and P729]. A pre-fabricated **Box Store** [P768] was put up in 1980, later being an

Ammonium Perchlorate Store and then a **Clean Lead Store**. A **K-round Cleaning** building [P763] was constructed by the **Small Proof Stand** [P753] in 1981 and was also pre-fabricated.

6.5. R AREA

6.5.1. Period IV 1900 - 1913

In response to the development, Cordite MD (MoDified), which contained less NG than Cordite Mk 1 but required a greatly extended drying period, land to the south of Black Ditch was developed for the first time. The majority of R Area is taken up with Cordite Tray Stores. These were also called water stoves and were serviced by a canal system cutting in from the Old River Lea in the west. By this time, the nitroglycerine for Cordite MD was supplied by the Edmonsey Factory on North Site and in comparison to the small self-contained Mk 1 factory on Quinton Hill, the MD operation was a large-scale production project.

Cordite MD also used a solvent (acetone) to increase extrudability and to gelatinise the GC/NG, therefore facilitating the pressing process. Significant amounts of acetone were used, and lost in the drying process. Acetone was an expensive import so development of an **Acetone Recovery Plant** [571] to the west of the stoves at this time shows that at least some of the solvent was being recovered. In the initial stages of drying, a larger percentage of solvent was given off in comparison with the later stages when an exterior horny layer has formed on the propellant and solvent release was more slow, even under steam heated conditions. From the press houses, the freshly extruded cordite strands would have been ferried on trays to the Acetone Recovery Plant where the solvent rich fumes were drawn over salts. Conversion of the acetone into a different chemical by the salts allowed later recovery of the acetone itself. From the Acetone Recovery Plant the trays of cordite were loaded onto barges and ferried to the Tray Stoves.

By 1904, forty tray stoves had been constructed, all were served by the canal network. Cordite was brought by barge from the **Acetone Recovery Plant** [571] to the loading porch and the trays unloaded. The trays were stacked on racks in the stove and left in the heated environment for several days.

Other buildings in R Area at this time have a function related to the post drying stages of the cordite MD process. **Blending Houses** [R614 and P710], **Packing House** [R601] as well as a **Cordite Magazine** [P712]. There were also smaller buildings, earth closets and hose houses associated with this area.

During 1908 the area around the Acetone Recovery Plant was improved by the addition of a **Caustic Acid Store** [571A] a **Crane** [571B] and an **Earth Closet** [585].

6.5.2. Period V 1914 - 1918

The expansion of production in the 1st World War is represented in R Area by the construction of four similar stoves directly below the southernmost line already existing [R657, R658, R659, R660]. These stoves were served by an extended

canal cut coming from the existing cut serving the stoves to the north. There was a dead-end canal on the western side.
Twelve tray stoves on a larger plan were also constructed, and oriented E/W rather than N/S. Shortly after these had been constructed, most of these larger stoves were converted to be Cordite Blending Houses, probably fulfilling an increased demand by wartime production. The larger stoves were also served by a tramway that had been extended southward from Area P.

The usual provision of hose houses and E.Cs were also added with this extension work.

On 10th December 1917 **Cordite Tray Stores No. 25 and 32** were destroyed by fire and not rebuilt [R624], [R634].

6.5.3. Period VI 1918 - 1938

The lack of development in R Area during this period is mirrored over the whole site. No new buildings were constructed and it must be imagined that, with a sudden downturn in production, many were moth balled and some may have seen use as temporary stores.

6.5.4. Period VII 1939 - 1945

During 1940 four new buildings were constructed which signals a return to Cordite production on a larger scale. Two new **Acetone Recovery Plants** were constructed in the centre of the R Area stoves [R621], [R626]. A **First Aid Centre** [R600] and an **Air-Raid Refuge** [R661] were also built. The threat to the factory from the air was real and many of the shelters were gas-proofed with an airlock as well as benches and twin elsans.

On the 4th October 1940, **Cordite Tray Stove No. 15** [R609] was destroyed by enemy bombing and was never rebuilt.

6.5.5. Period VIII 1945 - 1991

During this period forty new buildings were constructed in R area. During the final phase of use, R Area was used by Inter Services Research Group (I.S.R.G), Project I and Project III. Within the area the building usage consisted of magazines, climatic tests, plastic propellant development, labs and offices.

I.S.R.G :- This development area seems to have occupied the southern end of R Area. Due to the nature of I.S.R.G, it is difficult to say precisely which buildings were occupied. It has also proved impossible to link particular building projects to named research projects. There does seem to have been some pyrotechnic research and initiator testing as well as some handling testing, with bump tests and a drop tower. Apart from this, it is vague as to what was going on. In the 1980's, work was done to develop bomb glass for use in City of London Offices and elsewhere (T. Stemman Per. Comm.).

Project I :- This was the plastic propellant development project. Five buildings in R Area were used, [R646] for **Plastic Propellant Blending**, [R632], [R647] and [R648

]for **Plastic Propellant Mixing** and [R631]as a **Control Room** for [R632], [R647] and [R648] (all old tray stoves).

Project III :- This project was for the development of double base cordite. The buildings in
R Area associated with this project are [R601], [R602], [R603], [R612], [R613] [R614], [R616],[R615], [R627], [R628], [R637], [R686], all were used as **Explosive Stores**, with the exception of [R613] **Water Steeping** and [R614] **Cordite Rumbling and Graphiting** and were used as explosive stores ([R637],]R629], [R686] were new buildings post 1945).

Climatic Test Area :- This used seven buildings in R Area, [R625], [R645], [R634], [R633], [R645], [R638] and [R681]. [R635] and [R645] were converted tray stores with[R634]and [R633] being built post 1945 on the existing foundations of tray stoves. [R685], [R638] and [R634] were new buildings.

Magazines :- The remainder of the cordite tray stoves and the top north west corner of
R Area seem to have been used as general store magazines.

7. TRANSPORT NETWORKS

7.1. TRAMWAYS

7.1.1. Introduction

From its early days the RGPF had relied on water powered mills and water transport for processing and moving the raw materials and finished product into and around the site. On North Site, the construction of the steam-powered gunpowder incorporating mills (Group A), was accompanied by a short length of track running directly east/west from the charcoal mixing house to the new mills. This length of track was extended to the further new steam incorporating mills (C, D, E & F) during 1857 - 8. Despite the availability of water transport, the tramway seemed to be a better choice for this kind of work and the growth of tramways, supplying the necessary raw materials to the door of process buildings, in competition with the extensive waterway network, resulted in the use of ingenious swing bridges, lift bridges and tunnels.

7.1.2. Period II 1887 - 1890

A small section of tramway, operating between a **Wharf** [SS139] on the Old River Lea and the **Gunshed** [471] by the **Proof Butts** [M350]. There was a working Guncotton factory to the south of Cobbins Brook, but it seems as though the purpose for this, the earliest tramway on the South Site, was to supply powder or Guncotton to the proof range for testing. The account given in the Strand Magazine

points out that a range of guns were available for firing at the proof range and it is likely that the heavy guns would also have been transported on the tramway to a waiting barge. The tramway would have probably used and operated "flat fours" although no surviving track or bogies have come to light.

7.1.3. Period III 1890s

The development of a NG facility on Quinton Hill and associated Cordite Mk 1 factory to the south, on the north side of Black Ditch, led to an upturn in activity on South Site.

The existing tramway from Phase II was extended along the north of Black Ditch almost to the line of Sewardstone Road, where the **Dining and Shifting Room** [N591] stood. Off this main E/W route, branches peeled off to the various Incorporating Houses, Press Houses, Tray and Reel Stores.

The Quinton Hill NG facility was serviced by two branches of tramway. One came in from the **Acetone Stores** [N550, 481, 482] to the **Old Mixing House** [SS143] and **NG Store** [486], where it was met by two other branches servicing : The **Guncotton Store** [N540] and the **Weighing House** [SS145]; and **Guncotton Stove No.1** [SS147] and **Tray Store No.2** [N579]. These three branches would have been taking Guncotton from the store to be dried, bringing the dry Guncotton to the weighing house and then taking the dry Guncotton to the mixing house for the addition of NG from the store. The other branch came in from the Glycerine Store in the east, to the north of the two **Nitrating Houses** [476 & 477]. From here the glycerine bogey would have been hoisted up in the glycerine lift to the **Charge House** [SS144] that the two nitrators shared.

From the **Wharf** [SS139] on the Old River Lea; another extension ran northwards to a swing bridge across Cobbin's Brook, a waterway 30ft wide at this time. It seems likely that the tramway extended north from here into Lower Island, although there is no evidence for this. Running south east from the **Swing Bridge** [SS553] another tramline was put in to reach the **Stores** [468] and **Gunshed** [471], this then linking in with the existing N/S tramway running down to Black Ditch. Another branch also ran to the Gunshed from the **Powder Wharf** [405] situated just to the south west of the Swing Bridge. Also associated with the Gunshed was an extension eastwards to the **Magazine** [N500].

In the northern part of South Site, and associated with the Guncotton Factory, a length of tramway ran from the **Magazine** [G407] to the north side of the **Big Room** [G418]. The tramway ran most of the north side of [G418] and all of the western and southern faces of the building. It is quite possible that it also extended through [G418] into the eastern part of the factory [G431]. From the south face of [G418] a line also ran south to meet up with a branch from **Magazine** [N500], passing by, and through, **Blending House** [M348] before meeting up with the main E/W route along the north of Black Ditch.

Both the **Cordite Magazine** [M342] and **Blending House** [M348] had a tramway line pass through a concrete revetted gap in the traverse and up to the door, where

cordite could be unloaded for blending or storage, or loaded up for distribution. The tracks then left through a similar revetment in the opposite traverse. A separate tramline ran almost parallel to the line running through the traverse, but its route took it outside and away from the activity in that building.

The communications layout of South Site in 1894 shows a dependence on the tramway as a means of transport. Barges unloaded on the two wharves in the west on the Old River Lea, and from there all raw materials were carried eastwards to be converted into Cordite or guncotton, and returned to be loaded onto the barges and transferred to the filling factories or the Royal Laboratory at Woolwich.

7.1.4. Period IV 1900 - 1914

The tramways running north-east to join at **Swing Bridge** [SS553] were now extended in a single line running north onto Lower Island, thereby connecting the Guncotton and Cordite MD Factories with the pre-existing Black Powder Works. The line ran over Cobbin's Brook and then for about 350 yards along the east side of Lower Island before swinging to the western side and continuing for another 150 yards past **Acetone Stores** [385, 387] and terminating by the **Machinery Store** [381].

The branch running north from **Magazine** [N500] was now joined to the **Cordite Wharf** [405] by an east-west length of track running from south of the Guncotton Factory, parallel with Cobbin's Brook, to connect with the pre-existing junction near **Guncotton Stove No.17** [M338]. A spur was constructed to connect this building with the track running between **Wharves** [405 and SS553] and the **Gun Shed** [471]. A spur was also built from the Gun Shed to the new **Dry Guncotton Packing House** [466].

In the vicinity of the Guncotton Factory new development entailed more track building. The tramways now ran in front of the **Pulping and Moulding Room** [G418] and **Nitrating House** [G431] and behind. Cobbin's Brook had been substantially widened by this point, and the tramway ran flush with the bank along the back of the **Vat House** [422] and **Nitrate of Soda Store** [423]. These two branches were joined at both the western and eastern end. The western loop (as it connected with the new east-west line to Lower Island) ran through the **Coal Elevator** [415] supplying the **Boiler House** [419] and to the Building Works Department Yard to the west. From there the line ran out onto the main east-west track or back in towards the Guncotton Factory.

The eastern branch served the new **Nitric Acid Factory** [425], **Boiler House** [G440], **Nitric Acid Concentration Plant** [436] and **Sulphuric Acid Concentration Plant** [435]. In the latter, the line ran through a long transit shed on the south frontage and round the back of the building, reconnecting with itself just south-west of the Boiler House.

The building development associated with Cordite MD manufacture is reflected in new tramlines built during this period, particularly in the newly developed Cob Field.

Just south of the spur servicing **Cordite Magazine No.2** [N500], the line branched to the south-east. It branched again, one line going south and by-passing **Blending House No.2** [M348] before joining up with the north-south line again. The other continued south-east before turning south through a revetment in the traverse of new **Blending House No.3** [N547], allowing loading and unloading of cordite. It passed through the south traverse and branched, one line joining up with the tramway system serving the Quinton Hill area, the other continuing south, over a **Bridge** [SS555] over Black Ditch and into what is now Area P.

This tramway branched off to **Packing House No.3** [R601], **Blending Houses No.4 and 5** [R614, P710] and **Cordite Magazine Nos. 3, 4 and 5** [P712, P714, P716]. The latter branch bifurcated, the northern section heading north to end at a **Landing Stage** [405] on Black Ditch, on the other side of which was another new spur connecting the landing stage with **Packing House No.2** [N579]. These tramways facilitated the movement and distribution of Cordite MD in a period when re-arming for the inevitable war was paramount.

7.1.5. Period V 1914 - 1918

The principal feature of the establishment during World War I was the adaptation of existing cordite buildings to the manufacture of Cordite MD, the construction of twelve Cordite Tray Stoves to the south of Cob Mead (now Area R), and the building of seven Reel Stoves, two Reeling Houses and a Blending House in Cob Field (Area P).

The new Tray Stoves were linked to the manufacturing areas by a tramway extending west, then south of **Cordite Magazine No.2** [P712]. The line ran between the lines of stoves, branching off to each one in a staggered fashion. This allowed the unloading of cordite to be dried, and the subsequent movement of the dried cordite to the **Blending Houses** [R614, P710, P715]. Similarly, cordite could be moved to and from the other Tray Stoves on the canal system by means of two **Landing Stages** [587, 592] abutting the railway to the west and east sides of the southernmost canal extension.

A similar tramway system was built to connect the Reel Stoves in Cob Field with the cordite production plant on Quinton Hill and the Blending Houses. A new extension swung round the eastern end of Black Ditch by the **Filter Bed** [527b] to connect Quinton Hill with Cob Field. The increased movement of cordite in the area of **Blending Houses** [R614, P710], and a new looped tramway link, there necessitated the construction of a **Traffic Controllers Office** [P711] in 1917.

In the Guncotton Factory modifications were made in the east to include the **Nitric Acid Concentration Plant** [436, 436a], and generally to facilitate movement of materials around the plant. The guncotton yarn was transported to seven new **Guncotton Yarn Drying Stoves** [472a-g] in the vicinity of the Proof Range, and was dried on trucks before being moved to the two **Dry Guncotton Yarn Stoves** [460a, 405b] along another new branch line running north past **Guncotton Stove No.26** [M338].

During 1916-17 an 18" narrow gauge railway was constructed which joined together the various parts of the RGPF and connected it with the main line system (Jenkins pp392-401). It was planned in 1915-16 and was constructed mainly in 1916. Starting at Great Hoppit on North Site, it was 1 5/8 mile long, and ran south under Highbridge Street, over the old River Lea, and onto Lower Island. Here it joined the existing railway and ran south over **Swing Bridge** [SS553], through the cordite factory. Where the line ran to the Tray Stoves on Cob Mead it branched west and then south to a coal siding and interchange siding with the Royal Small Arms Factory at Enfield.

The construction of the tunnel under Highbridge Street and onto Lovatt's Mead was a difficult operation in that the line was to run parallel alongside the river. This necessitated the construction of a concrete coffer dam on the eastern side of the river, allowing just enough room for boats to pass. At this point, the line was 3 feet below the river level.

The railway crossed the old River Lea south of the tunnel at Lovatt's Mead by way of a swing bridge pivoted around the midstream of the river. At the south end of Lower Island, the **Swing Bridge** [SS553] was shore-mounted and gave access to South Site. Having run through the cordite factory, the line passed the **Acetone Recovery Plant** [571] and continued on to the Royal Small Arms Factory.

The interchange siding at the south-east of the RSAF gave access to a branch line to the north of Brimsdown station and thence to the main Cambridge line of the Great Eastern Railway.

7.1.6. Period VI - VIII 1919 - 1990

Though the factory continued to expand after World War I, the relative lull on the South Site did not necessitate the construction of new tramlines. It is likely that a larger proportion of the haulage was performed by battery locomotives, and that traffic still moved between the areas of the factory through the tunnel under Highbridge Street. After the factory ceased explosives manufacture in 1943, the Explosive Research and Development Establishment continued operations, but the tunnel link was dismantled by 1952. Some of the lines were still in use in 1954, but were out of operation soon after.

It is likely that most of the rails were removed and roads built over the tram routes, but no excavation has as yet been undertaken to test this. Most, if not all, of the light railway had been dismantled by 1961, though it is hard to ascertain exactly when.

The only use of tramways after this date is highly localised. The **Ballistic Assessment Facility**, centred on [M343], was constructed in 1966 with the aim of testing propellants to determine their qualities, and to determine changes if necessary. A 5" gauge tramway with a rail either side of a 3" RSJ was associated with the facility, and was probably constructed in 1966 (WASC 1126/32-36). The only remaining section after it was largely dismantled in 1983 is a 10m section of RSJ running through the south traverse of [M338], with the concrete base intact up

to the ditch. Research into the remote handling of explosives probably prompted the construction of the 5" tramway, in an attempt to test methods of negating the need for human operatives in potentially dangerous explosives handing facilities. The line then ran from [M343] to two **Curing Ovens** [SS209, SS211] and a **Magazine** [SS213]. Three turntables (WASC 1126/30-31) allowed the direction of the trucks to be changed, the first inside [M343], and one opposite each of the **Curing Ovens** [SS213] and [SS209]. The tramway also serviced **Firing Point** [M338], running over the filter bed north of [M343] on a bridge, and then through a 34" diameter concrete tunnel out through the southern traverse surrounding [M338]. From [M343], it probably also ran west over another bridge to **Magazine** [M340]. The propellant was carried in small trucks pulled by a sealed electric engine.

7.1.7. Tramway Infrastructure and Rolling Stock

Early tramways on North Site are known better through an 1877 design drawing of a lifting bridge to the Group E Mills [Jenkins p 388-9]. The rails were made of wood and tempered on the upper and inside surfaces with a jacket of iron (practice that had been adopted in collieries as early as 1716) The rails were 2ft 3inch gauge and sat on a wooden platform 4 feet wide. By 1891 the factory had adopted an 18 inch gauge system, at least on South Site which used turntables that can be seen on the 1894 map of the site.

The trucks used on the tramway at Waltham Abbey by World War I would have probably been hand-operated bogies up until World War I, with four wheels running on an 18 inch gauge track that allowed for light curves to be laid and narrow entrances to be negotiated.

During 1916 the disparate systems on North Site, South Site, Lower Island and RSAF Enfield, were consolidated into one partly locomotive powered system. The RSAF at Enfield was connected to the standard gauge through a siding at Brimsdown. New 30lb rail was laid on wooden sleepers which allowed 30 feet radius of curves, a gentler curve than had previously been possible. Locomotives used would have probably been BEV battery locos in the works, but it seems more likely that several Rushton, Proctor & Co 'ZLH' class locomotives were used on the main line, which ran from Edmonsey to the **Acetone Recovery Plant** [571]. These ran on paraffin and had slow-acting engines delivering 10 Bhp and very suitable for pulling a line of trucks.

To the west side of the site, and now demolished by the Flood Relief Channel, there were exchange sidings onto standard gauge tracks which were shared by South Site and the RSAF at Enfield. It must have been a hive of activity in this area as there was also an Acetone Recovery Plant, a Coal Yard and Coal Tip for filling barges waiting in the Old River Lea, as well as a Boiler House and Drum Store.

7.1.8. Safety

Operating a combustion engine on an explosives site had obvious dangers and so precautions were taken to reduce the risks by passing the exhaust through baffles and boxes filled with pebbles.

The Rushton, Proctor & Co locomotives would probably have been used to run the main line, as previously mentioned, but within the factory, either hand power or, after about 1917, 'electric tractors'. These electric machines were increasingly used on site. They had a 40-48 volt motor they could haul as much as 5 tons.

7.2. CANALS

The network of waterways on South Site are all on one level, unlike on the North Site. They were connected to the higher levels of waterway on North Site via the lock at Lower Island. Both Black Ditch and Cobbins Brook, that extend east-west accross the site, may have been used for early canal traffic into the site. They are linked to the river Lea at their western ends, and from here barges were drawn south, past the Royal Small Arms Factory at Enfield Lock, and along the Lea Valley until they reached the Thames below Blackwall. Ordnance would then have been carried on to the Royal Arsenal at Woolwich or to the magazines at Purfleet.

Developed in two stages, the whole of the South Site canal system serviced the tray drying stoves in Area R. The barges used would have been a standard developed on North Site in the years before South Site existed as a part of the factory. Evidence of barge traffic is provided by the footbridge by [R605] that crosses Black Ditch. Its semicircular shape is no hindrance to traffic on the canal and other examples can be seen on the North Site.

The first canal system, built in R Area in 1903-4, joined the first phase of cordite tray stoves to the River Lee. This canal system did not extend to the stoves [R601], [R614],[P710]and [P712], which were serviced by a separate tramway system with [R601] also being serviced by Black Ditch, which was widened in 1902. The **Acetone Recovery Plant** [571] was probably connected to the rest of the factory by the River Lee.

The second phase of canal was built in 1916 in conjunction with the last row of **Cordite Tray Stoves** [R657],[R658], [R659] and [R660]. This canal did not extend down to [R656], [R662], [R663], [R665],[R666], [R667], [R668], [R669], [R671], [R672], [R673] and [R676]. These buildings were serviced by a tramway which was connected to the canal system by the **Landing Stages** [587] and [592], opposite [R657] and [R660] respectively.

Swing bridges and lift bridges were used to overcome the existence of tramway and waterway together (see Tramways). Eventually the canals silted up and were not in use by the 1960s. The exact date the canals became impassable in this area is unknown, however document WASC438 (dated 1946) suggests that the canals in this area should be revived and it seems reasonable to suggest that at least some of them had become silted up by this time. Roads have now been constructed over the old lines of canal, but subsidence of the road often points to their existence below the surface.

7.3. Roads

The management of the research establishment could never have expected to maintain a tramway or canal system with the reduced traffic on site. Probably in the 1960s, the canals were filled in and the tramway lines lifted before roads were laid over their routes. The roads on South Site, especially in Area P, follow the original course of the tramway and as these are slightly raised, it is probably to make use of a high dry existing surface.

Trucks in [P712] **Truck Drying** (Dilly Carts) can be seen to have wheels for road use rather than track. It would be fair to suppose that they were pushed around the site on the roads.

8. POWER NETWORKS

8.1. Muscle

As in most early industrial processes, manpower would have played a major part in the movement of materials within buildings, and between processes, though in comparison with North Site, the use of manpower to, for example, turn screw presses, would have been fairly limited. This is primarily due to the later age of South Site and the commensurate preference for machines to do the work of men.

Men and boys were employed to push tramway wagons between process buildings up until the First World War, but the use of larger trams, and of greater frequency, plus the inception of the 18" railway linking the areas of the site, required the introduction of other motive power.

Manpower may also have been used to move barges around the site, as there is no evidence for the use of horses to do so. A horse can be seen on a 1903 photograph (PRO Supply 5/861) involved in the digging of the canals - it is hitched to a bogie either moving soil out, or bringing lining clay into the canal cut, but this is clearly not explosives work.

8.2. Steam

Steam power was undoubtedly used in the Guncotton Factory from the late 1880s onwards. Power was required for the mechanical teaser, beaters, potchers, centrifuges and a convenient rotative movement could be supplied by an overhead drive shaft. Our only evidence for this is indirect in the form of period photographs showing chimneys connected to the factory (1894 PRO Supply 5/860/74; 1896 PRO

Supply 5/860/59). The presence of **Coal Yard** [SS157] by 1888 also supports the presence of boilers.

In 1902-3, **Boiler House No.7** [419] was constructed to the west of the main guncotton pressing area, together with two **Economiser Chambers** [417, 418]. Fuel was supplied in the form of coal, transported by tram and delivered to the Boiler House via a **Coal Elevator** [420] straddling the track at the rear of the Boiler House adjacent to Cobbin's Brook. **Boiler House and Pump House No.8** [G440] was constructed in 1904 to provide steam power for the new acid factory.

8.3.

THE STEAM SUPPLY

There is hardly any surviving evidence for the early steam supply on South Site. There are no overall service plans for the period before the mid-1960s. The steam pipes in use at the time the site was closed in 1990, appear to date in large part from the mid-1960s, when the '**New Boiler House**'[G405] was built as part of a major rationalisation of the steam supply. However, as the early boiler houses were, in each case, replaced directly by mains supplies linked to the New Boiler House, it seems likely that subsequently installed service pipes followed the pre-existing layout in most cases.

Some information about the pre-1966 steam supply can be deduced from the location of the early boiler houses, although not all were necessarily producing steam for the heating system.

The only boiler house marked on the 1894 Sandhurst map, **[N564]**, was located on the north bank of Black Ditch, in the cordite section, which it presumably supplied with both steam and electricity during the 1890s. In 1902-4, three new boiler houses were built. The main **Boiler House No.7** [419] was built in 1923 beside Cobbins Brook, presumably to supply the Guncotton works, again with both steam and electricity (WASC 900/62A). Another **Boiler House**, **No.8** [433], was constructed adjacent to the guncotton works and probably served the Acid Concentration Plant. The third **Boiler House No.9** [499] was constructed in c.1904, at the junction of Black Ditch with the River Lea. It probably supplied electricity and steam to the newly-built cordite tray stoves in the south-western extension of the site.

Two further boiler houses were built between 1908 and 1923. **Boiler House No.6** [405d], was located adjacent to the main boiler house, beside Cobbins Brook. It may have supplied the widely scattered buildings in area M. **Boiler House No.10** [622] was built beside the River Lea, on the south-western edge of the site. The purpose of this latest addition is uncertain, as the cordite tray stoves in this part of the site were probably supplied with steam from **Boiler House No.9** up until 1908.

The absence of an associated dynamo or power house in the vicinity of **Boiler House No.10**, in contrast to the other boiler houses, suggests that it might have been purpose-built to heat the cordite stoves in the south-west part of the site, perhaps in response to the construction of additional stoves in 1908.

By 1923, the Cordite Section **Boiler House** [527] had been converted into a shifting room [N564]. The **8 inch steam main** [SS501], and **6 inch main** [SS502] were probably first established at the time of this conversion (c.1920?), to carry steam from the main **Boiler House** [419] to the Cordite Section. Another **6 inch main** [SS503] was installed, probably at the same time, to carry steam from the terminal of the **8 inch main** [SS501] to the process buildings in the south east part of the site (Area 'P'). [SS502] terminates next to [N564], from where it supplies all of the process buildings in Area N, with the exception of those forming the RDX Plant. [SS503] crosses Black Ditch, and supplies all of the process buildings in Area 'P'. Area 'P' was probably originally supplied directly from the Cordite Section boiler house, before the latter's conversion c.1920.

By 1923 there were therefore five boiler houses, numbered from 6 to 10 (numbers 1 to 5 were on North Site). All were located close to canals, presumably to facilitate fuel transportation. The later **Boiler Houses** [405d, 499, 622] are positioned well away from the process buildings, probably to reduce the fire risk.

At some time between 1923 and the mid-1950s, Boiler Houses 9 and 10 were replaced by a **6 inch steam main** [SS504], linking Boiler House No.6 with all of the process buildings on the Western half of the site, including the cordite tray stoves to the south of Black Ditch.

In 1966, the boilers were rationalised in order to reduce fuel costs. The 'New Boiler House', which was built on the site of Boiler House No.6, eventually replaced all of the earlier ones. Numbers 7, 8, 9 and 10 had all been demolished by 1976, the latter two to make way for the Ramney Marsh Flood Relief Channel.

There are very few traces of the pre-1966 steam infrastructure surviving on the site. The first **Boiler House** [527] is still present as part of [N563], but has been substantially altered internally. The boilers were removed by c.1920. No intact steam pipes survive from this period, but the line of the **6 inch steam main** [SS504] is marked by a series of reinforced concrete pipe hangers, which, although of uncertain date, were certainly installed before the mid-1950s, when plans were put forward for replacing this main with a new 8 inch one (the plan does not seem to have been carried out). Probably the earliest surviving steam infrastructure is a line

of three wooden steam pipe hangers, leading to **Box Store** [M349]. This building, which has been a box and tray store since its construction in 1892, retains many original features, including its internal steam heating pipes. The pipe hangers, which approach the building from the east, each consist of a plain, circular-sectioned wooden post, with an iron bracket attached to the top to hold the lagged pipe in place. Short sections of 2 inch bore iron pipe remain in situ, set into the tops of two of the posts.

After 1966, the whole system was served by the New Boiler House alone. The principal lines of supply included the **8" main** [SS501], which fed two **6" mains** [SS502 and SS503], linking buildings on the eastern side of the site (areas N and P respectively, and the eastern part of area M). A **6" main** [SS504], leading directly from the main boiler house, supplied area R and the western part of area M. Most of Area G was supplied by a **4" main** [SS530], leading eastwards from the main boiler house. Service pipes supplying individual buildings, or groups of buildings, were most commonly of 2" diameter, though some areas, notably the RDX plant, had a 3" supply, and a few buildings only 1".

Probably from the mid-1950s, but certainly by the mid-1960s, steam pipe runs were installed to a standard design, consisting of a cast iron pipe of variable bore, lagged with fibreglass wrapped in mineralised felt, and held in place with chicken wire. The pipe was normally supported at a level of c.1.2m, carried on concrete anchors, embedded into the ground at occasional intervals, and suspended from 'D type' hangers at more frequent intervals (c.7m apart). 'D type' hangers were circular sectioned tubular mild steel upright posts set into concrete bases, with a crossbar welded to the top, from which the pipe was suspended. The pipes were carried over roads and canals on 'A' and 'B type' hangers, also constructed from tubular mild steel set into concrete bases. These had two upright posts and 4 cross-bars each. 'A type' hangers measured 18' tall from top to ground level, 'B type' hangers 13'6". The size of anchor points and hangers varies according to the bore of the pipe. Stop-cock operated valves occur wherever service pipes leave the mains and at mains junctions. A slight (probably recent) variation in this design occurs in [SS553], linking the **8" main** [SS501] with buildings [M345] and [M348]. In this case, the 'D type' hangers are bent over at the top to form the horizontal pipe suspension bar.

After the 1960s steam rationalisation and during winter, the **New Boiler House** [G405] was supplying steam for heating around the site but there is evidence that some buildings had their own small steam boiler for use in the summer, when operating the main boiler would have been uneconomic.

This form of pipe support remained in use until the closure of the site in 1990, and therefore usually survive on the ground. However, the steam pipes supplying the buildings in the southern part of R area were dismantled before 1984. All that

survives in that area are the concrete anchor points and hanger bases.

The steam services within individual buildings vary widely, but are typified by the pipework in the rows of cordite tray stoves in the south-western part of the site (area R). In these buildings, the steam was supplied from a **6" main** [SS504] via a 2 inch service pipe, entering the building through one of the gable ends. The steam was fed into radiator pipes running down each side of the building, close to floor level. The cordite tray stoves have either two or three pipes running down each side, linked by external U-bends at each end of the building, through which the steam circulated continuously.

8.4. GAS AND ELECTRICITY

A **Gasometer** [SS161] is in evidence adjacent to the Guncotton Factory by 1897, and may have been supplied by the North Site Gas Works. These produced gas until about 1905 and the assumption that gas was thereafter obtained from local municipal supplies is borne out by the construction of a **Gas Meter House** [439a] at Quinton Gate in 1907-8. Gas was presumably used for lighting factory buildings and roads, possibly even motive power, but the presence of a **Gas Engine House** [SS148] adjacent to the **Old Mixing House** [SS143] on Quinton Hill between 1891 and 1894, may indicate that gas heating was being used for maintenance of regular temperature in the Mixing House and perhaps also the **Nitroglycerine Store**[486]..

A **Heater** [SS146] existed at the same time, and may also have been gas-powered although probably it used heat exchanged from steam, providing heat for **Guncotton Stove No.1** [N575].

The first electricity on South Site was generated by steam, and used for lighting purposes. A **Dynamo house** [525] is annexed to the Quinton Hill **Boiler House** [N564] in 1894, and the addition of a **Switchboard House** [526] in 1896 may indicate the installation of generators. The **Mixing House** [486] rebuilt in 1894 over the NG Stove retains a complete lighting circuit with 'Maxlume' lamp boxes and encased pipes; the **Washing House** [N544] also has most of its original fittings from the same date.

In 1905, a purpose-built **Power House** [G403] began to supply South Site with electricity, and may have provided North Site with power until the construction of the North Site Power House between 1908 - 1915.

By World War One, electricity carried all over the factory by overhead transmission lines with ceramic insulators, superseded steam as the primary power source. The use of electricity at all levels of activity within the factory is further indicated by the construction of two **Electric Tractor Charging Houses** [430a, 510a] in 1917.

The RDX facility used small electric motors situated outside the process building with a shaft evidently coming through the asbestos wall to deliver motive power to the interior. In many of the post war buildings, electric motors were located in a central alleyway, where they could be serviced and replaced if necessary. The drive shaft passed through the thick wall into one of the process bays where the work was done. All these motors were controlled remotely, allowing a greater degree of safety.

Where electricity is carried around structures, it tends to be routed around the outside of buildings in electricity supply ducting. Many services to process buildings are accessed from the exterior in this manner so that the need for entry is limited to a minimum.

8.5. LIGHTING

Early danger buildings lighting was usually provided by exterior electric bulbs shining through a sealed window pane, as can be seen in **Mixing House** [486] and **Washing House** [N544]. During the Second World War these were usually encased in an enamelled green tin box with access panel for bulb changing. It was only when a truly sealed unit was developed that electricity and light could be brought into the danger building itself. Many of the more modern structures have fluorescent strip lights which are encased in a sealed unit using rubberised rings at either end.

Electric power was carried around the site on wooden poles equipped with ceramic overhead transmission line insulators. Two poles from the turn of the century can be seen close to the **Box House** [M349] that was constructed in the 1890s. They have dates carved on them of 1901 and 1902, although this cannot be taken as a definite date for erection, as a storage period may have occurred after they were dated. Many similar poles can be seen in historic photography of the site.

Comprehensive coverage of the layout of street lighting on South Site after 1950 is documented on plans held by RO on South Site. No attempt has been made to understand this more fully in this report.

9. NON MANUFACTURING FACILITIES

9.1. ARCHAEOLOGY OF SAFETY

The factory's prime objective was to produce propellant and high explosive for the Armed Forces. However, the personnel employed were protected by safety procedures and certain laws, the 'Explosives Act 1875' for example, set down guidelines for the storage and handling of explosives.

9.2. TRAVERSES

The early Nitroglycerine facility on Quinton Hill had huge brick built traverses (blast walls) filled with earth. They proved flawed in their design during May 1894 when they added debris to the blast from the NG explosion, causing more damage rather than less. As a result, most of the danger buildings on South Site are provided with traverses, usually of earth with a concrete revetted entrance way or tunnel. These traverses come up to the eaves height of the building inside and are provided to allow more buildings to be placed in a given space than would be possible without traverses. Some later traverses were also constructed during the Research and Development phase, utilising Braithwaite Tanks, a steel tank that was filled with gravel or sand. These were positioned to divert blast from a testing facility or to ensure blast did not carry in a certain direction.

Danger buildings are all required to be earthed with lightning conductors, the first statute (Victoria, 1860, ch.39) was an indirect result of work by Sir W Snow-Harris on lightning conductors at Waltham Abbey (RCHME, 1993, p159). South site has a good collection of conductors from different times throughout its 100 year history. These would have been connected by a copper strip to an earthing plate, or rod, made of copper or lead. Usually there are at least two conductors, one at each end of the building, although some have four or more.

9.3. FIXTURES AND FITTINGS

The fittings for explosives processing buildings are always made of non-sparking materials. Copper, brass and lead are used extensively for window catches, hinges, handles and locks as well as for tools. Wood, cotton and leather were used for tools and clothing. A rare survival on South Site is the leather floor in [M348] which is secured down with copper tacks. Later floors were made of lead, all of which have been removed, and gritless asphalt. Cleanliness would have been central to every worker's day and a floor designed with no corners for dust or dirt to accumulate was easier to quickly sweep clean, this can be seen in many of the buildings where the floors survive.

9.4. FIRE FIGHTING

Early signs of a fire-fighting capability on South Site are shown by the construction in 1900-13 of a **Hose House** [448] in Area G as well as in Area R. During the First World War, a **Fire Engine and Hose House** [451A] had also been constructed. During the Interwar period, another two **Hose Houses** [448, 621] were built in Areas G and P respectively. A system of hydrants was probably in effect that allowed hoses to be connected to a head of water sufficient to produce a powerful jet.

It was not until 1954 that the **Fire Station** [P754] with its hose drying tower was constructed and a permanent site fire brigade was available. They would respond to internal alarms given over the site telephone system. Many of the buildings on site contain sprinkler systems, often hand operated by workers inside the building.

Later developments saw infra-red heat detectors being used to automatically drench fires in process buildings.

9.5. Police

The role of the Waltham Abbey RGPF Police has been extensively studied by a present day policeman, Mr. Bryn Elliot. The original force were a group of workers willing to stay on an extra shift and do the rounds of the factory. Provision of a Police Hut on South Site from the 1890s onwards shows a security presence on site. In the aftermath of the 1894 explosion, a criticism was made concerning the public visiting the site at weekends. Soon after 1894, the Police Hut is moved to the Gate at Quinton Way where they would be more effective in checking personnel. The present day security force are situated in [G454] but are a private security firm.

9.6. Welfare

Welfare facilities for the workers were somewhat sparse to start with. Washing and dining rooms have always been available and it seems that the allowance for a worker to have half an hour or so to wash and change at the end of each day was expected in such an explosives environment. No mention is made in this report of the numerous toilets constructed on site over the last hundred years.

Hospital facilities were available on North Site at the Sandhurst Hospital from 1894, and later, the World War One Women's Hospital Sandhurst annexe. South Site's **Surgery** [P748] was constructed opposite the **Fire Station** [P754] in 1954.

10. THE TECHNOLOGY OF EXPLOSIVES MANUFACTURE

10.1. GUNCOTTON

Guncotton is manufactured by the action of mixed nitric and sulphuric acids on cellulose. The product is a cellulose nitrate but has become known as Nitro Cellulose (NC).

Although Guncotton had been known from 1833, a series of fatal accidents, notably in 1847 at the Faversham Works in Kent where 20 lost their lives, led to reduced interest in the new explosive.

During the mid 19th Century Baron von Lenk continued experiments in Austria (RCHME 1993, p180) and concentrated on the problem of producing a strongly nitrated cotton. His method was to take skeins of cotton and clean them before drying thoroughly. The dried skeins were then immersed in the strongest acids available for forty eight hours before removal into a stream of water, where they remained for several weeks to wash all traces of acids. Finally they were washed in a solution of potash.

Abel continued experiments at Waltham Abbey North Site and in 1864 he patented the pulping and pressing of Guncotton. This improved method used short cotton fibres, for which cotton waste was an ideal raw material. Teasing of cotton waste removed foreign objects and opened up the fibres to allow good penetration by the acids. The pulping after nitration and initial washing resulted in efficient removal of trace acids which had hitherto caused decomposition within the nitrocellulose. The resulting pulp could be moulded with hydraulic presses to form cylinders or discs.

Manufacture of Guncotton as a practical explosive was further helped by the discovery in 1859 that wet Guncotton, a relatively stable and safe substance, could be detonated by a dry Guncotton primer and detonator.

In 1873 the boiling of Guncotton after nitration was found to help stabilisation and was widely adopted. Development work continued on the North Site at RGPF where the Highbridge Street Guncotton factory was active.

Although Abel's method was taken up enthusiastically by many private manufacturers, there was a major development in 1905 when the nitration process was changed to the Thomson and Thomson displacement method from Abel's dipping method. Large earthenware pans containing mixed acids, were filled with the cotton and then weighed down with perforated earthenware plates. Fumes were guided off by means of a fume hood and nitration took about two and a half hours. On completion of nitration, the acids were run off by means of an earthenware cock at the base of the pan and the cotton was washed through with water. From the

nitrating pans, the cotton was taken to the boiling vats where trace acids were removed, then to the pulping room where it was pulped in the beaters between rotating knife blades. It was then run over a grit trap and blanket run to remove any foreign matter before being run into the potchers where it received a final wash before being added to the greater mass of pulped nitrocellulose in a tank capable of holding four tons.

In 1885 construction started on the Quinton Hill Guncotton Factory. There was plenty of room to stretch the factory out westwards along the south side of Cobbins Brook from the existing farm buildings. The farm and its stables were utilised as stores and offices.

In its early days, from 1887 to 1905, the factory was laid out to manufacture Guncotton by Abel's Method. This is clearly laid out in Younghusband's "Description for the Manufacture of Abel's Pulped and Compressed Guncotton at Waltham Abbey" (1873 referring to the Highbridge Street factory).

Cotton waste, imported to the factory from the bleachers was stored in the eastern end of [G431]. **The Cotton Waste Store** [430] is at the eastern end of [G431]. Once the cotton had been picked over it was taken to the next room along in [G431], the **Teasing Room** [429C]. The cotton was run through the teasing machine to open it out and then through a rag-cutting machine in the same room to cut the fibres into 3 inch lengths. The **Teasing Room** was heated by steam heaters to assist in the drying of the cotton waste.

Once the cotton had been fully opened up by the teasing machine it was transferred on a conveyer to the **Drying Room** [429B], where it entered a drying machine. The cotton carried along the length of the drying machine by an endless band, being subjected to warm air at
82.5 °C. It was dropped onto successive endless bands, of which there were eight in all, and on exiting the machine the cotton had been thoroughly dried. It was then weighed into the proportions needed for nitration and placed in metal boxes and sealed before taken to the **Cooling Room** [429A]. Here the canned hot cotton was left for 24 hours to cool.

Once cool the cotton was ready for dipping in the **Nitrating Room** [429]. There were two phases of Guncotton nitration. Firstly the cotton was dipped in a pan of fresh strong acids for a few minutes. These pans were kept cool by sitting in a stream of flowing water and the acid was ladled by hand from a distribution tank into each pan. Then the cotton was removed and, after a quick squeeze to remove excess acids, it was steeped in acids once more, except this time in an earthenware pot. These were taken to the **Vat House** [422] where they remained, cooled in a stream of cold water, to digest in the acid for 24 hours.

The following day the pots were taken to the centrifugal acid extractors, probably located in [422a], north of the Nitrating Room, where the contents of six pots could be spun at one time. Waste acids collected were bottled and returned to Mr. Barnes of Hackney (Younghusband, 1873).

Next the nitrated cotton was washed, to remove free acids remaining and wrung out several times. Younghusband mentions the recent development of using hot water instead of cold at this point, soon it would be standard practice to boil the nitrated cotton as well as washing it.

From the soaking tanks the nitrated cotton left the acid side of the works and started on its second phase of manufacture. Directly it was taken to the Beaters, a separate building [442B] was constructed for these machines by 1923 but it must be imagined that they were housed in either the **Vat House** [422] or [427] the **Pulping and Moulding Room**. Here the nitrated cotton was processed through rotating knives in an amount of water until it was in a thoroughly divided condition. This took about four hours and allowed the pulped nitrated cotton to be pumped through pipes to the Poachers, also housed in **Pulping and Moulding Room** [427]. In the poachers the pulped nitrated cotton from eight Beaters was bought together for a final and complete washing. The Poacher was an iron pan 18 feet x 9 feet x 4 feet deep, containing a revolving drum. It was in the Beating and Poaching that Abel had developed Baron von Lenk's method.

The final washing was in an alkali solution to ensure all free acids were neutralised. This alkali solution consisted of "500 gallons of lime water, 3lbs of whitening stirred up in a bucket of water, and 61lbs of soda caustic dissolved in boiling water". Storage of all these ingredients would certainly have been nearby, perhaps in the farmhouse **Stable Block** [SS137].

Still in its pulped condition, the nitrated cotton was sucked up into a Stuff Chest which had an agitator to stop the settling of finer particles in the nitrated cotton. From the Stuff Chest, charges of around 1/2 lb of guncotton were drawn down into gauge tanks and from there into 36 moulds, where the excess water was drawn off through wire gauze strainers by means of a vacuum pressure. This produced a cylinder measuring about 9 inches. Moved by a carriage on rails to a hydraulic press, the cylinders were reduced to 5 inches in length and then, at a more powerful press, to 2 inches. At this point they become more discs than cylinders.

All the presses were powered by an hydraulic accumulator delivering a pressure of 1000 lb/inch sq.

The guncotton discs were sometimes drilled, to take a fuze, and sometimes not. They contained about 15% water and were fairly stable. Before storage in sealed tins, more water was usually added to increase the water content to 30%.

Younghusband also mentions that the standard Waltham Abbey 3 inch diameter, 2 inch thick disc weighed 9oz when dry and contains on 2% water.

Some years later, in 1909, Sir Frederic Nathan delivered a paper "Guncotton and Its Manufacture" (J.Soc.Chem.Ind. No.5, 193-205) to the London Section of the Society of Chemical Industry. The outline of processes then in use at the Royal Gunpowder Factory, Waltham Abbey, which he described allows us to explain some of the developments seen on historic maps and plans as well as on the ground today.

On the whole, Abel's process was still in use except for the method of nitration, to be described later.

In the **Teasing Room** [429C], the rag-cutting machine had been removed from the process as it was found to felt the cotton at the edges which had a detrimental effect on the action of the acids on the cotton. In the drying machine, the cotton waste was dried in three quarters of an hour and had only to be left for 8 - 9 hours in the **Cooling Room** [429A].

Nitration had changed very much. Since Abel's method, experiments had developed varying processes using similar hardware but adapting it to save time and labour. On the continent, a nitrating centrifugal was the latest development and it delivered a 160% yield for a one hour nitration. However, the displacement method was adopted. In August 1905 the displacement method, devised by the Thomsons, J.M & W.T, of the Royal Gunpowder Factory, was introduced to South Site and an expansion of the factory was seen.

The change to nitrating is not now obvious, as the same space was used by very different plant installed in it. Large earthenware pans with fume hoods stood in groups of four and were serviced by a collection of lead pipes. These pipes led to the nitrating acid supply pipe, the strong and weak waste acid pipes, and to the waste water pipe. All these came through a gauge box that allowed control of the flow as well as allowing for specific gravity to be measured.

The pans are filled with 650lb of mixed acids from the inlet pipe below after a perforated bottom plate has been inserted. Then dry cotton was introduced by hand (c.20lb). Perforated plates of earthenware were then place on top of the cotton, so that the level of acid came halfway up the depth of perforation. Then a stream of warm water was poured over the top of the acid into the perforated plate. This ensured no fumes escaped from the nitration which took c. 2 ½ hours. At the end of nitration the waste acid was allowed to exit the vessel from the bottom outlet at a rate of 17lb/minute while water was introduced at the same rate from the top. This method seemed to improve the stability of the finished product, as the warm/hot (40°C) interface of acid/water passed through the whole charge as the acids were displaced off, which effected some denitration. Despite this meaning that nitrogen contents of over 13.4% are unlikely, the guncotton is in effect given a preliminary boiling. The displacement process produced a 170% yield.

After nitration the nitrocellulose went to be boiled. Between 1894 and 1905 the boiling of guncotton was done in twelve stages; the first stage took two hours and the time was increased for each subsequent boiling through 4, then 6, 9 and eventually 12 hours for the last two boilings. With the advent of a new nitration process in 1905, experiments with boiling were carried out resulting in a process with ten boiling stages. After two boils for 12 hours, a cold displacement wash was given and then a further five boils of 4 hours and three at two hours. This method was calculated through experimentation and testing of acidity of the wash waters through the industrial process and may have been helped by the use of a very hard water, as is found at Waltham Abbey. It may be that the **Vat House** [422] contained the boiling vats used in this part of the process.

After pulping the guncotton was run in a water solution through grit traps, blanket runs and electromagnet traps to remove any foreign bodies. Nathan seemed surprised at the quantity of foreign bodies recovered at this stage.

From the traps the cotton was moved to the Poachers where it was paddled in fresh water three times, settling each time for the scum to be skimmed off.

Some emphasis is put on the thorough blending of cotton at all stages of the process. Teased cotton is placed in the nitrators and when the boiling vats are filled, a mixture of nitrating pans is loaded into two boiling vats. From four boiling vats, 32 beaters are charged in another mixture. These 32 beaters are then loaded into 8 poachers which produces a uniform percentage nitrogen, fluctuating between 13.05 and 12.93% N in tests carried out on 600 tons of guncotton manufactured.

Moulding and Pressing then follow similarly to Abel's method.

10.1.1. ACIDS

On South Site it has been supposed that the manufacture of Nitric and Sulphuric Acids needed for Guncotton and Nitroglycerine manufacture did not take place until the construction of an acid factory to the east of the Guncotton Works in the late 1890s (see Area G). Prior to this development, acids were bought into the factory in the quantities needed for mixing (Younghusband 1873).

The presence of a **Nitrate of Soda Store** [423] in the early 1900's demonstrates that Sulphuric Acid was being imported, probably concentrated on site, and then used to manufacture Nitric Acid by its action on Nitrate of Soda. A side product of this reaction is Nitre Cake, for which a crusher was provided and this crushed product was sold on to be included in Harpic scouring powder. As with all things at Waltham Abbey RGPF, the purity and strength of the acids used was regarded as equally important in the struggle to find a superior explosive or propellant. Only the best acids would have been bought in but the control afforded by being able to make acid on site would have soon been a necessity.

During the 1905 expansion of the Guncotton factory, the facility for manufacturing acids was also increased. **Sulphuric Acid Concentration Plant** [435], **Nitre Cake Store** [432] and **Nitric Acid Concentration Plant** [436] were all built in 1904-5. This facility was probably supplying acids to the RDX manufacturing process in the 1950s, before it went out of use and was finally dismantled.

It is worthy to note that construction of an acid factory for the North Site was also started in the late 1890s, so both sites were separately provided with acids.

10.2. NITROGLYCERINE

10.2.1. EARLY MANUFACTURE

Only small amounts of NG could be made by the earliest manufacturing methods, about one hundred grams being standard. The basic nitrating vessel was a pot of mixed acids standing in an outer vessel of cold water, into which the glycerine was poured slowly and well stirred by hand. The NG formed settled out from the waste acids and was run off through a separating funnel into a water tank where it was washed. NG manufactured in this way was impure and unsuitable for long storage.

Larger amounts were manufactured by increasing the number and size of nitrating pots. Other modifications included the mechanical pouring of glycerine, and of the mixing. As greater care was taken in purifying the mixed acids, so the purity of the NG also rose.
Following Nobel's dynamite breakthrough, demand for NG in Europe increased dramatically in the late 1860's and beyond, and a refinement in NG manufacturing process occurred as a result. Large cylindrical lead tanks were used as the nitrating vessels, between the tank and an outer wood case cold water was circulated, and also in lead pipes within the tanks themselves. Agitation was maintained by compressed air fed through lead pipes, though earlier plant still used mechanical means as well. Glycerine was run in from a higher level vessel, the inflow to the nitrating vessel controlled by a cock. A glass pipe led from the cover of the nitrating vessel to carry off fumes, and also to observe the degree of nitrous fumes formed. If these latter were too abundant, and the thermometer in the cover registered too high a temperature, the charge was drowned in a large water tank directly beneath the nitrating vessel.

When nitration was complete the whole charge was run slowly into a large water tank, where the mixture was agitated with wooden paddles, either manually or mechanically. The NG sank to the base of the tank and was drawn off into smaller tanks, where it was washed several times with water and soda solution until neutralised.

Despite this improved method, it still had several disadvantages; all the waste acids were lost, a large amount of nitrous fumes were produced, and overheating during nitration was likely if the inflow of glycerine into the nitrating vessel was not carefully controlled.

10.2.2. NEW NG FACTORY, QUINTON HILL

Following the patenting of cordite in 1890, Colonel Noble, RGPF Superintendent, travelled to Germany to inspect the NG plant at the Rheinsiche Dynamit Fabrik, part of the Nobel Group, at Opalgen near Köln. He returned with recommendations that the German Factory be used as a template for the new Waltham Abbey factory, including the purchase of appropriate plant from Germany. At home, Mr. McRoberts of the Nobel factory at Ardeer, where NG had been manufactured since 1873, advised on certain modifications that could be made, including the injection of the glycerine into the mixed acids. The plant that came into operation at Waltham

Abbey by March 1891 was a compromise between the Oplagen plant and McRoberts' suggestions.

Using the process described below, the efficiency and output of the RGPF works increased steadily. Given that in theory one hundred parts of glycerine will produce 246.74 parts of NG, the following Figures will illustrate this point :

	parts NG/100 parts glycerine
Early processes	< 200
Later processes	200 - 210
RGPF (1890s)	214.25
RGPF (Nathan-Rintoul)	220.18 (Nathan & Rintoul 1908:195)

It is worth briefly describing the preparation of the raw materials involved in the manufacture of nitroglycerine, namely glycerine, nitric acid and sulphuric acid, as the processes operating in 1891 at Quinton Hill were improvements on their forerunners. Following that, an analysis of the three periods of Quinton Hill factory and then a description about RGPF NG manufacture as a whole.

10.2.3. GLYCERINE

Stored in the **Glycerine Store** [N540] until required, the Glycerine was obtained from different suppliers/mixed to ensure uniformity. For example, in 1894-5 at least, glycerine was purchased from Price and from Watson, the latter apparently being of poorer quality (PRO Supply 5.491). The blending took place in ten ton iron tanks, one batch of glycerine corresponding to one batch of nitrating acid. The glycerine was heated until fluid enough to be blown by compressed air into a galvanised iron tank in the **Charge House** [N543], which had coils for heating or cooling the glycerine as required. When needed for nitration, it was run into the glycerine tank in one of the **Nitrating Houses** [476, 477] where it would be measured accurately, rather then weighed, before use.

10.2.4. NITRATING ACID

Nitric acid and Sulphuric acid were at the outset purchased from suppliers. Acid for nitrating cotton at the Guncotton factory was purchased from a Mr. Barnes of Hackney (Younghusband, 1873). Manufacture on site did not happen until the acid factory was built in Area G in 1896 (see Acids).

10.2.5. March 1891 - May 1894

The NG factory was built on Quinton Hill on the principle that the chemicals could flow through the processing plant largely under the force of gravity. Where this was not possible, compressed air from the **Air Reservoir** [SS150] was used instead. At the highest point of the factory was the **Charge House** [N453], into which the glycerine and acids come prior to nitration. The glycerine came from the **Glycerine Store** [N540] to the east, and the nitric and sulphuric acids mixed prior to being lifted into the Charge House by way of the **Glycerine Lift** [SS149]. Below and to either side of the Charge House were **Nitrating Houses Nos. 1 and 2** [476 & 477], each surrounded by a solid brick traverse.

From the Charge House a charge of 1054lb of nitric and 1785lb of sulphuric acid was run into the nitrating vessel which was a large lead tank with a convex bottom, containing lead coils filled with cold water or brine, and compressed air feeds. It had a domed lead cover, cemented on, with glass inspection windows. Air pipes, acid pipes and water inlet/outlet pipes also passed through the cover, as did a "manlid with an acid lute" at the centre and through which the glycerine injector was passed. When the injector was not in use, the hole in the manlid was closed with a loose lead plug. Also fixed in the cover was a fume pipe fitted with a glass cylinder to allow visual inspection of the fumes given off during nitration. At the base of the tank there were two earthenware cocks; if the temperature during nitration rose above 22°C, either cock could be opened and the charge drowned in the water drowning tank beneath the nitrating vessel. One cock was also connected to the separating tank via a moveable lead bend.

Once the acids were run into the nitrating vessel and cooled at 16° C, the glycerine was injected under the surface of the acid via compressed air spray. During the 45-60 minutes a 350lb glycerine charge took to be nitrated, cold water was circulated through the coils, and agitation maintained via the compressed air feeds. After nitration the injector was removed and the charge cooled to 15° C before being run into the separating tank through the earthenware cock at the base of the nitrating vessel.

The separating tank was a square lead tank with a base sloping inwards to the central hole fitted with a vertical glass cylinder, to which was attached a flow-branched horizontal pipe, each branch with an earthenware cock. Underneath the separator was a lead-lined wooden safety tank to contain the charge should the glass cylinder have broken. One of the cocks was connected to the drowning tank in case the temperature rose too quickly or too high. Surrounding the separator was a glass-panelled skeleton frame cover with sides sloping upwards to a fume pipe. Air pipes led into the separator through this cover.

The charge remained in the separator for about 40-45 minutes as the NG separated out forming a surface layer about 4.5 inches thick. Most of this layer was run off through a side earthenware cock to a preliminary washing tank. The waste acid was run through the bottom pipe to the **After-Separating House** [475], so that the acids could be recovered. When the remainder of the NG was seen coming through the pipe, the cock to the After-Separating House was closed and the one to the pre-

wash tank opened. Any sludge remaining in the separator was piped to the **Wash Water Settling House** [N574].
The pre-wash tank was open, and the waters were agitated by a compressed air pipe lying loosely on the bottom of the tank. The NG was washed three times with water, and a fourth time with soda solution. Once the NG has sunk to the bottom, an upper earthenware cock was opened and the wash waters run to the Wash Water Settling House, whilst the NG was run off through a lower cock south of the **Washing House** [N544].

There were two lead-lined wooden barrels containing a soda solution to remove any acids still adhering to the NG. Both were on a raised platform under which was a drowning tank, into which the charge would be poured if the temperature rose above 50°C. Compressed air lines mixed the 750lb NG charge thoroughly with the soda solution and when agitation ceased, the NG sank to the bottom of the barrel. A lower cock was opened and the clean NG run into a filtering tank. An upper cock discharged the wash waters to the Wash Water Settling House.

The filtering tank was a lead-lined wooden tank, in its cover an open-ended cylinder was passed, the bottom end of which was fitted with a wire gauze attached to a solid metal ring supporting a flannel bag filled with salt. The NG was run through the top end of the cylinder and into the salt filter, where any remaining water was absorbed and flocculent matter retained. The NG was then run down another covered lead-lined gutter to the **NG Store** [486]. The salt bag itself was wrung out, and the used salt dissolved in warm water to recover any further NG; both solutions were sent to the Wash Water Settling House.

All the water used in the NG process was sent to the **Wash Water Settling House** [N574] and held in a large wooden tank agitated by compressed air. At the end of a production run the air was shut off and the NG allowed to sink to the bottom of the tank, where it was drawn off and returned to the pre-wash tank in one of the **Nitrating Houses** [476, 477].

At the end of the week the 'mud' that accumulated at the bottom of the tank was drained off and taken to the **Mud Washing Shed** [506]. The mud consisted mainly of sulphates, often as much as 80% lead sulphate, containing some NG. By means of hot water and soda solution, the NG was washed out of the mud through flannel filters suspended over a small lead washing tank. This removed the NG, made the mud alkaline and converted the sulphates to carbonates, making the mud less likely to decompose. As a last precaution, the mud was wrung in flannel to remove the last small amounts of NG, mixed with paraffin, then burnt.

All the waters from the Wash Water Settling House and the Mud Washing Shed were discharged into two **Settling Ponds** [SS147A & B], adjacent to Black Ditch. Small amounts of stray NG sank to the bottom, but any potentially hazardous build-up was avoided by exploding the pond weekly using dynamite charge (Fitzgerald 1895:317).

10.2.6. MAY 1894 EXPLOSION

In the afternoon of Monday 7th May 1894, an explosion in the Washing House severely damaged the fabric of the factory, halved production, and killed four men in the process. The **Washing House** (N544) and **NG Store** (486) were completely demolished, and most other buildings in the area extremely damaged, including Nitrating House No.2, where a nitration was in progress.

SANDHURST RECOMMENDATIONS

The Court of Inquiry (see Sandhurst 1894) could not find any definite cause for the explosions, but proposed many suggestions and recommendations, particularly in respect of working practices. A new process for mixing NG and Guncotton was devised, in which NG would not be stored in liquid form, but was washed and poured on to the Guncotton as quickly as possible. The brick-revetted traverses were found to have added debris to the blast wave, and all new traverses were therefore constructed with earth, as they had been successfully at Ardeer, where several traverses had survived explosions.

The **Old Mixing House** (SS143), **Charge House** (N543) and **Weighing House** (SS145) were destroyed in the blast.

10.2.7. SEPTEMBER 1894 - 1903

Necessity dictated that the Quinton Hill plant be brought back into production as soon as possible and within six months, at an expenditure of £ 800 - 900 (PRO Supply 5/491), the plant was back in operation.

The 1891 **Nitration Plant** [476, 477, N543] was retained, and the **Washing House** [N544] rebuilt on the same spot but using a circular design and partly sunk into the ground. As per Sandhurst's recommendations, it and the other process buildings had its traverses rebuilt in a similar fashion to those at Ardeer, using a brick and earth construction designed to limit the amount of flying debris should an explosion occur.

A **Junction House and Covered Way** [484] was built to house and protect the guttering that led from the Washing House to **Mixing House No.1** [N575], converted from the Guncotton Store No.1 and to **Mixing House No.2** [486], which was built on the site of the destroyed NG Stores. **The Heater** [SS146] previously supplying the Guncotton Stove was demolished. The Mixing Houses were built to replace the **Old Mixing House** [SS143], which was destroyed in the explosion, and that there were two of them reflects the new process modification whereby the NG was mixed almost immediately with Guncotton in the Mixing Houses.

Sandhurst had remarked that the RGPF, like private factories, should not be allowed to store NG in large liquid quantities, and this adaptation was a direct response to

this recommendation. The urgency to mix NG into relatively inert cordite paste quickly may be seen in the conversion of the Dry Guncotton Store into a **Mixed Material Store** [N553], where paste could be stored until required.

As before, the Guncotton was weighed prior to mixing, now in the new **Weighing House** [503] built to replace the obliterated [SS145]. **The Wash Water Settling House** [N574], **After Separating House** [475] and **Mud Washing Shed** [506] remained essentially the same, though minor structural modifications were required to repair damage received in the 1894 explosion.

One recommendation of the Sandhurst Committee was that another NG factory be built further from other explosives manufacturing areas. In 1898, a new NG plant was constructed in the relatively isolated area of Waltham Abbey North Site known as Edmonsey Mead, to the same basic principles as the rebuilt 1894 Quinton Hill plant. One of the major exceptions to this similarity was the construction of a purpose built acid factory on the west of the North Site to supply pure acids to the **Nitrator** [E2]. Previously on Quinton Hill, acids were obtained from commercial firms, including Nordhaven, and blended to ensure uniformity.

1903 - 1908

As early as 1895, it had been noted that the use of earthenware cocks in the NG manufacturing process was far from desirable. James M. Thompson, Superintendent of the RGPF Guncotton Factory, remarked that while the earthenware cocks supplied by Boulton were of a high quality, those supplied by Smith were downright 'dangerous' (PRO Supply 5/491).

The main problems associated with their use were the friction potential if grit became lodged between cock and key, and also the danger of NG remaining in the cock after it had passed through it. By 1902, there were no cocks used in the process subsequent of the separating tank.

In January 1901, an explosion occurred in the cock leading to the drowning tank in **Nitrating House No.2** [477] as a result of trace NG remaining in the key after the charge had been run through it. If the charge had not already been drowned, the explosion would have been of much more serious nature.

The hazard problem of earthenware cocks was solved in 1903 by the introduction of the Nathan-Thomson-Rintoul process (Eng. Pat. 15983, 1901) using what was termed a 'nitrator-separator'. This plant was installed in **Nitrating House No.1** [476] and was in operation in May 1903 (PRO Supply 5/710).

The nitrator-separator was a cylindrical lead vessel whose bottom sloped to one side. Inside were cooling coils, the turns of which were infilled to prevent NG lodging in any interstices; the cooling water entered through one side of the vessel. and branched out through the coils, the flow of which was controlled by a cock on the outside. Compressed air pipes also entered through the sides, just below the surface of the nitrating acids.

A conical cover, into which a thermometer was inserted, was burnt on, ending in a small cylinder with glass inspection windows. In one side of the cylinder was an air pipe for suctioning off fumes with compressed air. Another pipe connected the top end of the cylinder with the pre-wash tank. The pipe conveying the nitrating acids ran vertically down the side of the tank, and back up in a U bend into the bottom of the vessel. thus ensuring that no NG could get into it. There were two branches on the acid supply pipe, each with an earthenware cock; one led to the waste acid egg, the other to the drowning tank. This latter was controlled by a long rod terminating in a handle on the operating platform. On the key of the drowning cock were two further cocks; one on the drowning tank compressed air pipe, one on the water supply pipe, and both opened by turning the drowning cock key.

When the cock on the acid tank was opened, the mixed acid ran into the nitrator-separator via a cock on the acid supply pipe, the cocks were closed again when sufficient acid was run into the vessel. The acid was cooled by the coils, a glycerine injector inserted in the cover, and the nitration started.

During the nitration, the temperature of the cooling water was regulated, and sometimes refrigerated if necessary. The advantages of refrigerated water were that the nitration was completed in reasonable time, the loss of nitric acid due to volatilisation was reduced, and that the constant nitration time allowed the factory to be run in a more systematic fashion.
Nitric acid fumes that did arise were piped into a Guttman condensing tower and approximately 18lb of nitric acid could be recovered per ton of NG produced.

Once the nitration was finished, the injector was removed and the NG allowed to settle for a few minutes. It is at this stage of the process that the innovation is essential. The acid from a previous nitration would have been stored in a displacement waste acid tank in the Nitrating House, but only just before the current nitration began. This same waste now entered the bottom of the tank via a cock on the displacement tank and on the waste acid supply pipe. The NG was therefore displaced, through the top of the vessel, into a gutter, and into a pre-wash tank. The nitrator-separator was left full of waste acid until next required for use.

This method meant that the NG was removed from the acid quickly, therefore reducing the risk of overheating, and also not allowing flocculent matter in the NG to accumulate as a thick sludge between it and the acid. It also increased the life of the vessel itself because it was not exposed to acid fumes; previously, both cover and coils had to be overhauled about every three months.

The preliminary washing tank of the Nathan-Rintoul design had not earthenware cocks, but was instead a closed lead tank with a fixed cover, from which led a fume pipe, and also had an opening covered by a rubber flap. The NG was worked several times with water and then with soda solution to make it alkaline, all the time being mixed with compressed air. A rubber skimmer was used to run off the wash waters to a labyrinth; a funnel connected to a rubber tube was depressed, through the hole in the cover, into the tank and the water flowed over the edge and into the

funnel and tube. Most of the remaining NG separates out in the labyrinth and is returned to the pre-wash tank.

The guttering used to run the NG to the **Washing House** [N544] was modified also. To prevent freezing and potentially disastrous thawing of NG during cold weather, warm water was run through an outer jacket when necessary. Lap-jointed gutters were replaced with butt-jointed gutters, and scraped smooth on the inside. They were covered in canvas, fixed along one edge and laced along the other, facilitating cleaning and inspection. After use, the gutters were wiped with flannel to remove all traces of NG.

The Nathan-Rintoul washing tank in the **Washing House** [N544) also had no cocks and was lined with lead. Before the NG was run from the pre-wash tank the gutter was sluiced with warm soda solution, and afterwards also. The NG was washed with weak soda solution whilst being agitated with compressed air from a pipe which, as on the pre-wash tank, was affixed to the underside of the tank and holes bored through to allow air in. A fume pipe exited through a hood of rubberised cloth to draw off any fumes formed. The NG was washed at least the last two times with warm water, to remove as much sodium carbonate as possible. (Having had previous problems with limescale, the Nathan-Ritoul process used softened water, which was supplied from tanks in the **Charge House** [N543] to all process buildings).

The NG was run in water-jacketed gutters to a filtering tank in one of the **Mixing Houses** [N575,486]. This was a lead tank with a perforated lead fixed false bottom, on which were lain sponges sewn in flannel, and onto which the NG was run. The sponge filters retained water and matter in suspension, and also reduced the amount of sodium in the NG, a large amount of which affects flame luminosity. These filters were wrung to remove water and any NG still remaining.

The NG left the tank at the bottom through a rubber tube into a fixed lead burette, which accurately measured amounts of NG for emptying into rubber-lined canvas bags of Guncotton. This clearly satisfied the suggestion of the Sandhurst Committee that Liquid NG be stabilised as soon as possible. In addition, tests were carried out on the NG to ascertain purity and stability.

The **After Separating House** [475] was rendered defunct by the Nathan-Rintoul process, mainly due to the reuse of waste acids in the nitrator-separator. Those acids which were not to be reused were mixed with water to prevent separation of NG (Eng. Pat. 3020, 1903), and blown to the **De-nitrating House** [SS156] in the Guncotton Factory. Much waste acid was also taken to the Acid Factory on North Site for concentration. In 1902 for example, 204 tons of acid from Quinton Hill and 589 tons from the Guncotton Factory were taken to North Site and reused at Edmonsdey for the manufacture of NG there (PRO Supply 5/710).

The Quinton Hill NG Factory closed on 27th August 1903 because sufficient NG was being produced at Edmonsey. There was also some concern over the safety of contractors working in the area on the Cordite MD conversion scheme, in the event of an accident.

The plant was temporarily re-opened between May and December 1904, while Nathan-Rintoul plant was installed at Edmonsey. The nearly new Nathan-Rintoul plant in the renumbered **Nitrating House No.2** [476] was used throughout. The process was altered only slightly in that an extra water washing was introduced and the soda washing times reduced (PRO Supply 5/710). The introduction of the Nathan-Ritoul process was a success on two counts. From the efficiency perspective, NG yield at the RGPF increased 15%, while the amount of acids used was nearly halved. Safer plant and operating methods undoubtedly reduced both the potential and actual number of accidents.

In 1907-8, **Nitrating House No.3** [477], **After Separating House** [475] and the **Charge House** [N543] were demolished; it was intended that the bricks be reused to build a new and larger charge house, housing all acid, soda and purified water tanks, but this scheme seems never to have been put into effect. **Nitrating House No.2** [476] was also dismantled (PRO Supply 5/710).

The **Washing House** [N544] survives intact, and contains the original two washing barrels and other internal fittings. It has been the subject of a detailed recording project by Essex County Council Field Archaeology Group (E.C.C. Survey Report June 1996). **Mixing House No.2** [486] also survives relatively intact, including a galvanised metal internal lining, probably dating from the Second World War.

LATER DEVELOPMENTS

Batch processes such as Nathan-Thomson-Ritoul, which dealt with 3600lb (1633kg) NG charges, became considered too dangerous, even though relatively few serious incidents occurred. It became necessary to implement a method of continuous manufacture in which a smaller proportion of total output would be in the plant at any time.

The first such process was the Schmid process, first used in the Woolwich Research Department in 1934, and by 1936 was installed at the Royal Naval Cordite Factory in Holton Heath, Dorset. It was rapidly replaced by the Biazzi process after World War II which used simple and more compact plant.

The plant constructed at New Hill on North Site in 1940 was built in response to explosions in **Mixing House** [63] in January 1940, and **Mixing House** [46] in April 1940, and it would be expected that plant already in situ in other ROF's would be the blueprint for a new factory. The New Hill NG Factory never came into operation despite being completed. It is probable that there were problems with the gravity feed or pumping of acid along the pipelines from the acid factory to New Hill (RCHME 1993:101, 137). Severe subsidence of the mounds around the New Hill buildings may also have contributed to the plant not being used fully. Recently it has come to light that the New Hill NG facility was not commissioned because the compressed air eductors were not capable of raising the acid to the required height (Maclaren pers.comm).

Edmonsey NG plant continued to operate until September 1943 when the plant closed. As the Explosives Research and Development Establishment, the site continued operation after 1945, and from 1961 small amounts of NG were manufactured for research purposes, using plant, in the **Washing House** [E5] at least, installed for the Schmid process (RCHME 1993:137, 163).

On South Site after 1959, it was usual to obtain NG stored in kieselguhr after having been manufactured at R.O.(Bishopton) and then extract the small amounts needed for research projects in **NG Extraction** [N557] and later [N549] (see Area N 1945-1991).

11. PROPELLANTS

11.1. CORDITES

11.1.1. GENERAL

A uniform colloidal mixture of nitrocellulose and nitroglycerine. Cordite is the name given to many different types of propellant, usually extruded in cords of varying diameter. It was Alfred Nobel who really made the breakthrough in the late 1800s with the propellant 'Ballistite'. He discovered that mixed NG and NC formed a substance less energetic in its explosive qualities than either of the two main ingredients. Nobel used a 12.6% nitrogen content NC with Nitroglycerine and, interestingly, mixed the two in an aqueous solution before dewatering and then passing the paste through hot rolls to gelatinise the paste into a sheet of Ballistite. The sheet was subsequently cut into small squares. Very soon afterwards the British Government set up a Committee and in 1890 Cordite Mark 1 was recommended for Service use, manufacture at Waltham Abbey started in 1891 and it was introduced to the Service in 1893. Nobel's claim of patent infringement was not upheld as there were many small differences in the manufacturing process as well as in the ingredients.

11.1.2. SOLVENT CORDITES

Cordite Mark 1 was a mixture of 37% NC (13.1%N), 58% NG and 5% stabiliser in the form of mineral jelly. Initially included in the recipe as a barrel lubricant, mineral jelly acted as a stabiliser by mopping up the acidic products of NC and NG decomposition which could otherwise compromise its shelf life.

Although not an ingredient as such, a solvent was needed to facilitate mixing and allow for the dough to be extruded from a hydraulic press. Much emphasis was

placed on the quality and strength of the Guncotton and Nitroglycerine used in the manufacture and this can be seen by reference to these processes above.

THE PROCESS OF MAKING CORDITE MK I

The recent discovery of a paper on the manufacture of Mk 1 cordite at the Public Record Office at Kew, dated 1890-92 (SUPPLY 5.368), now allows us to consider the early factory remains in conjunction with the early process. The following description relies heavily on the new evidence but buildings have been identified to tie them in with the process as described.

It is assumed that the nitroglycerine is made and stored in the tank in the **Nitroglycerine Store** [486], that the dry guncotton pulp is stored in the dry guncotton store, which stood within the traverse now surrounding N500, and that the acetone and tannin are available in their store, which would also contain a supply of empty 'subcharge' vessels. The Acetone store was known to have stood on the present position of N550.

Firstly the proportion of tannin (1.3 lbs) for a subcharge was placed in the subcharge vessel, and then the measured proportion of acetone (2.6 lbs) run in. These, and subsequent proportions, are those for a 13 lb incorporation machine, making Cordite. The tannin dissolves readily in the acetone, and the vessels, carefully covered over, to prevent the escape of the very volatile solvent, were conveyed at once in light covered trucks, to the **Nitroglycerine Store** [486]. Here a charge of nitroglycerine (7.15 lbs) was run into the tannin solution, from a suitable measuring reservoir in immediate connection with the main tank. The completed nitroglycerine subcharge was then taken at once carefully covered over to one of the **Incorporating Houses** [N567, N572, N568, 511], in covered trucks which acted as small expense stores.

The guncotton subcharge (4.55 lbs) was weighed out in suitable hoppers constructed so that when placed on the incorporating machine, they covered one half of the open top of the latter. The guncotton subcharges were taken direct to one of the **Incorporating Houses** [N567, N572, N568, 511] in trucks similar to those used for the nitroglycerine subcharges.

A hopper, containing a guncotton subcharge was placed on the incorporation machine, and the machine set in motion. The nitroglycerine subcharge was slowly run in from its vessel on to the knives of the incorporating machine, and the guncotton hopper started. Care was taken to begin with the nitroglycerine subcharge to avoid friction between the dry knives and the dry guncotton pulp. The charging of the incorporation was so regulated, that the two subcharges were expended simultaneously. As soon as the incorporator was charged, the hopper and vessel were removed at once, and sent to their respective stores, and the machine immediately hermetically closed. Incorporation was complete in 6 hours.

When the incorporating was completed, the machine was stopped, the cover removed, and the charge taken out at once by hand, and transferred to earthenware guncotton pots. This was done as quickly as possible to prevent the charge drying.

In these pots, which are provided with closely fitting covers, it was sent to the **Pressing House** [N562].

In the **Pressing House** [N562], the material was fed into a pug mill which delivered it into the press cylinders. When charged these cylinders were fixed in position in the pressing machine, which squirted the material into cords of the required thickness. From the commencement of the incorporating until the material came from the pressing machine as cord, every possible care was taken to prevent its exposure to the air.

The thicker natures of cord, used for cannon cartridges, was, as it left the pressing machine, delivered into an endless band provided with knives. The distance between the knives was regulated so as to cut the cord into lengths suitable for the particular cartridge for which it was intended. The pieces of cord were removed as they were cut from the band by hand, and collected in shallow trays.

The fine cordite for small arm cartridges was wound, as it left the press, on large drums, having circumferential partitions, so that the number of turns in each partition when cut right through forms one long bundle giving the requisite number of pieces for cutting up into charges.

Both the trays containing the large cannon cartridge Cordite, and the bundles of fine small arm cartridge Cordite, were removed to a drying house, which was well ventilated and gradually dried at a temperature not exceeding 80° Fahrenheit. When all the solvent had been driven off, the finished cordite was packed into suitable wooden cases for transport to Woolwich.

SUPP 5/368

Early developments

This process is interesting as it had been previously thought that the only ingredients for Mk 1 cordite were nitroglycerine, guncotton and mineral jelly. Certainly another paper in the same document at Kew (SUPP 5.368) states the Vaseline (55 lbs) was ordered to make up 1050 lbs of cordite each week. Perhaps the early developments in the manufacturing of the new propellant meant that changes in the proceedure were inevitable. Shortly after the 1894 explosion in the Quinton Hill NG facility the NG Store [486] was rebuilt and soon afterwards is renamed **Mixing House** [486], this as a result of recommendations in the Sandhurst Report. So the process had already changed by the time that the Ordnance Survey 1897 Edition map was produced and at this time the manufacturing process is explained as follows:

The ancillary buildings for the manufacture of cordite are grouped to the east and west of the factory itself. To the east the **Glycerine Store** [N540] was connected to the factory by a tramway. Three Acetone Stores were located to the south of the Glycerine Store in a row from east to west. N550 now stands where **Acetone Store No.1** originally stood. The other store, **Mixed Material Store No.2** [N553], with a

latrine attached on the north east corner, was also connected by the tramway system. To the west guncotton was stored in a magazine, located within the traverse now surrounding N500. Boxes and trays were stored in **Box House No.1** [M349].

Acids were imported and transferred to the **Charge House** [N543] that sat between the two **Nitrating Houses** [477, 476]. Glycerine was also brought to the Charge House by tram and when the correct quantities were in place the two ingredients were run into one of the Nitrating houses on the start of their gravity powered journey to become Nitroglycerine (NG).

The details of NG manufacture at Waltham Abbey are given in the Nitroglycerine section of this report (see 10.2 above). Nitroglycerine was delivered by gutter to the Mixing House where the correct amount of nitroglycerine was poured onto the guncotton contained in rubberised bags. The workers would then knead the two ingredients together to form a cordite paste. This relatively stable paste would be loaded into a leather box, brought from the **Box House** [M349] and then transferred to one of the **Incorporating Houses** [N567, N572, N568, 511]. Here the paste was kneaded by machines that had been adapted from the baking trade, basically a dough mixing process. The incorporation gave the paste a dough-like consistency and it was made more pliable by the addition of a solvent, acetone, from one of the Acetone Stores mentioned above as well as mineral jelly. The mineral jelly was originally included in the hope that it would lubricate the barrels. This does not happen because it is entirely consumed in the explosion, but it does have another very desirable effect. The presence of the jelly reduces the rate of erosion of the barrel by lowering the temperature of the explosion.

After incorporation the cordite dough would be ready for pressing or extruding in hydraulic powered presses. So the dough was either extruded in large cords for use in larger pieces of ordnance, or extruded in very thin hollow cords onto reels. The extruded reeled cordite was taken to be blended at the **Reeling House** [N569]. The larger diameter cordite was cut to fit the length of trays, brought in form the **Box House** [M349]. These trays had open diagonally slatted bottoms so that when they were transferred to the **Tray Stoves** [N552, N579, SS142] by train, they could be stacked and the cordite dried by allowing the hot air to circulate. The final process was to blend the finished product. This blending happened in the **Blending House No.1** [M348]. Blending is the simple but necessary process where different batches of cordite are mixed evenly with others to result in a uniformly mixed load of boxes. This blending ensures that the cordite is neither all very strong or very weak as small differences in the percentage of nitroglycerine or nitrated cotton used would alter the ballisitic performance of the cordite strands.

Finally the finished product would be stored in the **Cordite Magazine** [M342], waiting to be barged away to the filling factories, magazines at Purfleet or to the Royal Arsenal at Woolwich.

The Boer War taught many lessons, for Cordite manufacturing it highlighted the problem of excessive barrel wear. This was found to be due to a large percentage of NG (58%). Developments led to the new **Cordite MD**, or MoDified, being taken up as the Service Propellant. The need for large amounts caused the manufacturing facility for Cordite Mk 1 on Quinton Hill to be almost closed down as most of the process buildings were given over to storage. Most of the MD manufacturing (incorporating and pressing) was carried out in buildings on North Site. South Site concentrated on manufacturing the Guncotton and drying the cordite in R Area.

The main difference in Cordite MD was the percentage of NG used. The recipe is as follows: 65% NC (12.9 - 13.2%N), 30% NG and 5% Mineral Jelly. The manufacturing was very similar to MK 1 except that the drying took many days, depending on diameter, so the extensive Drying Stoves in R Area may be seen as an attempt to allow for this problem.

The factory at Waltham Abbey soon expanded to include all the sites at Waltham Abbey in the production of Cordite MD. Many of the old gunpowder process buildings on North Site were converted to cordite manufacture early in the 20th Century. The detailed process for manufacturing cordite MD is recorded by Bowditch (Bowditch 1983) in his account of the Royal Naval Cordite Factory at Holton Heath in Dorset and is reproduced here:

"Dry guncotton was then weighed into waterproof, rubberised bags which were taken to the Paste Mixing Houses where a measured quantity of nitroglycerine was poured on to the guncotton. This mixture was emptied on to a lead table where the charge was then given a preliminary kneading by hand before being gently pressed through a sieve of half inch holes at the end of the table when it fell into a bag attached below. This must surely have been a perilous operation. Marshall suggests, superfluously one would have thought, that 'no unnecessary violence must be used'.

The so-called 'paste' thus obtained was transferred next to the Incorporating Houses where it was placed in an incorporator. These machines were rather like a baker's dough mixing machine which could be warmed or cooled as appropriate with a water jacket. The appropriate amount of acetone was then added and the mixture was blended together for a period of about three hours after which the mineral jelly was added to the extent of 5% of the total mix and the incorporation process was continued for a further period of about three hours.

At this stage the produce, now called 'dough' was taken to the presses on the Cordite Ranges towards the north-west of the factory. Here the cordite dough was pressed behind a rope mantlet screen through a die in a hydraulic press, from which it emerged in the familiar cord-like form. The product was collected by hand as it emerged from the presses and cut into measured lengths. The cords were loaded on wooden trays of the kind already described which were, in turn, placed in a truck and taken to the drying stoves.

In the stove area the trays were placed initially in the Acetone Recovery Stoves. Here the trays were stacked in chambers heated by steam pipes. As each chamber was filled it was sealed with the exception of a small opening at the bottom of the door. Air was drawn by suction through the stoves over the cordite which was maintained at about 43°C. The acetone vapour passed through a pipeline, supported about eight feet from the ground, to the acetone recovery plant. After a period of about a week, when the amount of acetone given off had diminished to such a low level that it became uneconomic to continue the recovery process, the cordite was removed and taken to the final drying stoves. These were similar to those just described except that no acetone recovery equipment was fitted. This final drying period varied according to the diameter of the cords but it could take as long as four or five weeks.

Finally, after drying, the cordite was blended in one or more of several ways so as to ensure a constant quality product with uniform ballistics. All that then remained was for it to be packed, bonded and despatched by rail or, primarily, by barge from the cordite jetty."

Bowditch 1983

Cordite MK 1 and MD were not the only cordite types developed. Two other types were developed in reaction to a shortage of ingredients. During the First World War **Cordite RDB** was developed to allow manufacture using ether/alcohol as a solvent instead of acetone. This was in reaction to an acetone shortage and a lower % N Guncotton (12.2%) was employed to allow the NC to be dissolved in the ether/alcohol. The reliance on acetone is discussed later.

In 1933 production of **Cordite W** (Waltham) commenced. This used Carbamite (diphenyldiethyl urea) as a stabiliser instead of mineral jelly. During the Second World War shortages of Carbamite resulted in the replacement of two-thirds of the Carbamite with mineral jelly, known as **Cordite WM**.

Some years before the Second World War, further research into a propellant that produced less 'muzzle flash', a problem with Cordite MD, resulted in the incorporation of Picrite (Nitroguanidine) with the other ingredients. This flashless cordite was known as **Cordite NF** (No Flash).

Research into solvent extruded cordites continued and the number of variations tested is almost limitless, using varying percentages of nitrogen in the NC, different ratios of NC/NG and experimenting with ballistic modifiers and stabilisers.

11.1.3. ACETONE

The importance of acetone as a solvent in Cordite MD led to research into a method of recovering the acetone in the vapour given of by the drying sticks of cordite. Stoves were specially altered to allow the acetone/air mixture to be drawn off to an **Acetone Recovery Plant** [571], built in 1904, where the vapour was passed through

a series of towers against a stream of sodium bisulphate solution. The acetone combines with the bisulphate to form a soluble salt and from this salt the acetone is recovered by distillation with a solution of sodium carbonate.

Further Acetone Recovery Plants were constructed in the centre of Drying Stoves in Area R in the Second World War [R621, R626]. Eventually a fermentation process for acetone manufacture was obtained that could ferment readily available non-foodstuffs such as horse chestnut conkers.

11.1.4. SOLVENTLESS CORDITES

One of the more sensitive operations in the manufacture of Solvent Cordite is the pouring on of NG onto dry NC. As both are highly explosive and sensitive, moves were eventually made to avoid accidents by developing a safer method of mixing the two.

Nobel had used a mixing process for Ballistite where the NG and NC were combined in water, which was later driven off on a dewatering machine.

11.1.5. WET MIXING

The process known as 'wet mixing' was further developed in Germany for the manufacture of solventless cordite (1914-18), but was soon adopted as the generally accepted method of obtaining a mixture of NC and NG to which a solvent may then be added.

NC in an aqueous slurry was pumped through a revolving spiral mixer known as tundish, where NG was sprayed into it. The mixture passed steadily into a stirring tank where a homogeneous slurry of NC/NG was formed. This slurry was passed onto a dewatering machine which consisted of a continuous band of cloth passing over suction rolls and then under a weighted roller to consolidate the sheet of pulp. Passing then to an automatic breaker, fragments of the NC/NG pulp were deposited into aluminium trays. These trays were loaded into racks in an open-ended truck which was taken to a **Drying Stove,** [P712] is an example on South Site. This dry paste was then ready for incorporation.

Although a solvent could be added, the wet mixing process allowed Carbamite and Candelilla wax to be added in the stirring tank before dewatering, which produced a crumbly oatmeal like substance. Passing this through hot rolls at 55°C encouraged gelatinisation of the NC and sheets could be formed. This solventless product was extrudable, although much greater pressures were needed to press the waxy substance. The large horizontal press in [P716] is an example of such a press. The benefits of a solventless cordite are attractive: the lack of solvent means that no stoving process is called for, creating savings in time and money. The lack of drying period overcame problems associated with distortion and shrinkage in the solvent

cordites and a greater diameter of solventless cordite was possible as there was no need to try and drive off a solvent from a very large cord.

11.1.6. CDB (Cast Double Base)

Increase in size of cords shows a developing trend towards the use of solid propellant in rockets. Although Congreve had shown that a loose propellant would power a small rocket, research was now aimed a producing a solid charge bonded to the case wall in such a way that the burning takes place on the end and progresses steadily in one direction. This is known as a 'cigarette burn' and allows a rocket motor to provide a known thrust for a known period of time.

Research was shared between Waltham and scientists in the USA during 1951 (Information Exchange Project B29) and the American idea of casting a propellant charge was taken up and improved upon. The American idea behind a Cast Propellant was as follows: a single base (nitrocellulose) powder was used to fill a mould and was known as a casting powder. The other component, a casting liquid, is introduced from the bottom of the mould upwards under vacuum pressure. The casting liquid usually used is Nitroglycerine, desensitised with Triacetin (TA) which also acts as a plasticiser (for the NC).

The container used to cast the propellant was known as an inhibitor which formed the layer between the casing and the propellant. The action of NG being drawn up through the casting powder caused the inhibitor (cellulose acetate) to be partly gelatinised and become fused with the propellant. The whole motor was then removed to a curing house where it was subjected to temperatures of 38-70°C for three days or more (24" diameter would take 4 - 5 days) to 'cure' the motor.

Broadly this process was taken up at Waltham Abbey except that a few important changes were made in the ingredients to develop a more energetic charge. British propellant had been double-base (NC/NG) since Mk 1 Cordite in the 1890s and so the first change was to cast a double-base propellant using the American idea. This was the birth of CBD (Cast Double Base) Propellant research project, carried out mostly under the heading 'Project II' from 1952 onwards.
The nitroglycerine required for the casting liquid was extracted from dynamite in the **Nitroglycerine Extraction House** [N557], with its associated **Plant Room** [N558], both purpose-built buildings constructed in 1952. Here it was mixed with a desensitising agent such as triacetin, and a stabiliser, such as carbamite. The desensitised nitroglycerine casting liquid was then transported to the **Casting Liquid Magazine** [N579] built in 1952.

Performance was also improved using single-base powder. The Americans had achieved 200
lbs/lb. With double-base casting powder, this increased to 225-235 lbs/lb. Next the addition of aluminium powder (a highly exothermic combustible) with ammonium perchlorate as oxidiser into the double base powders produced a modified CDB known as CMCDB (composite modified) which gave a 240-245 lbs/lb. Ultimately the

addition of a high explosive such as TDX or HMX was soon to deliver a specific impulse 245-255 lbs/lb.

Research into flash suppression, smokelessness and cost efficiency were later carried out at IMI Summerfield. Rocket motors are now made with directional capabilities and much work has been done on the inhibitor casing, cellulose acetate being replace by strip laminate cases that absorb less NG during casting.

Problems with storage life of CDBs centred around the inevitable evolution of gases (carbon dioxide, nitrogen and nitrogen oxides) from the slow decomposition of nitric esters (NC & NG). These gases were less of a problem on small charges where porosity allowed them to diffuse. Carbon dioxide is reasonably soluble in double base propellant and the nitrogen oxides produced are effectively absorbed by stabilisers in the matrix (carbamite). Nitrogen continued to be a problem, especially as the inhibitor had to be at least as porous to nitrogen as the double base propellant itself.

11.2. COMPOSITE PROPELLANTS

Composite propellants are a physical mixture of fuel and oxidant, of which gunpowder was the earliest and best known and in which charcoal is the fuel, saltpetre the oxidant and sulphur, although partly fuel as well, is the binding agent between the charcoal and saltpetre grains.

Thanks to the American petrochemical industry, many polymers have been developed by chemists that are similar to the hydrocarbon molecule and are suitable as 'fuels' in a composite propellant. The 'oxidiser' used is almost always ammonium perchlorate, other salts being too energetic or producing noxious gases during combustion.

During the 1939 - 1945 war, cordite was used as the propellant in unguided rockets by the British Services. It was packed loose, partly to get over differential expansion rates between itself and the casing. The development of plastic and rubbery propellants after the 1939 - 1945 war was aimed at solving this propellant problem and ensured a reliable thrust over time from the charge employed.

11.2.1. PLASTIC COMPOSITE PROPELLANTS

Using Polyisobutylene (PIB) as a fuel and Ammonium Perchlorate as the oxidiser, a very hot, fast-burning propellant is obtained. The addition of ammonium picrate as a coolant was carried out early in the manufacturing process.

Manufacture : Ammonium Perchlorate, having been milled to the correct size and then thoroughly dried at 80°C, is sifted into an incorporator preheated to 70°C. Ammonium picrate is sifted in if necessary. A weighed amount of PIB is added from a steam-heated pan and incorporation is effected from a remote position. The dough formed is de-aerated through a perforated die-plate and from there it is taken to the cylinder of a hydraulic press and extruded directly into a rocket motor with a

former mounted centrally. The internal walls of the motor are treated with an adhesive to ensure secure bonding between propellant and motor wall.

The disadvantage of plastic propellants is that they tend to 'flow' under their own weight when temperature rises and the viscosity of the binding agent is impaired. Nevertheless, they are used in a wide range of military and non-military situations.

11.2.2. RUBBERY COMPOSITE PROPELLANTS

Based on the same principles of fuel/oxidiser mixtures, rubbery composites use a polyurethane rubber as fuel and ammonium perchlorate as the oxidiser.

Manufacture : Polyester is manufactured and freed from water before it is added to a heated stirring vessel with bottom run-off and vacuum line attached. The heated polyester has ammonium perchlorate, aluminium powder and a burning rate catalyst added before the lid is closed and the vacuum switched on to exclude air. The next stage is to add the liquid isocyanate from a burette, which has the effect of forming links between the molecules in the polyester. Swiftly the mix is 'cast' into a prepared motor case with a former in place. The assembly is then taken for curing, much like the CDB process.

These rubbery composites resisted the 'flow' problem of plastics but had to be stored in very dry conditions.

11.2.3. CMCDB (Composite Modified CDB)

It can be seen that the inclusion of ammonium perchlorate into the CDB cordites to form Composite Modified Cast Double Base propellant is, in at least a small part, the result of the Rubbery and Plastic Composite Propellant developments. It was added to the casting powder and cast in the usual way.

Problems Encountered : Carbamite, used successfully as a stabiliser in CDB, was useless in the presence of ammonium perchlorate and so a replacement was found in Resorcinol.

12. HIGH EXPLOSIVES

12.1. PICRIC ACID (TRINITROPHENOL)

Experiments were started in 1841 by Laurent who nitrated phenol. In 1869 it was discovered that if phenol was dissolved in sulphuric acid to give phenol-4-sulphonic acid, it nitrated more smoothly.

From about 1874, Picric Powder manufacture was authorised at Waltham Abbey RGPF. Frederick Abel himself worked on 'Picric Powder', a mixture of 40%

ammonium picrate and 60% potassium nitrate as a shell filling. It was not extensively used but later added as a booster for Picric Acid in shells.

In 1888 Picric Acid, under the name 'Lyddite' was adopted by the British Service and remained in use up to early years of the 1st World War and maybe as late as the 1950s.

It was not an ideal high explosive as incomplete detonation of Picric Acid charges in the Boer War resulted in clouds of unburnt Picric Acid forming on explosion. Accusations of 'poison gas' were made which led to the establishment of the Research Department at Woolwich, which set about looking for an alternative to Picric Acid.

12.2. TETRYL

(TRINITROPHENYLMETHYLNITRAMINE)

ALIAS C.E. OR COMPOSITION EXPLODING

Developed at Woolwich during the search for a replacement for Picric Acid(see 12.1 above) and probably because of the relatively easily obtained raw material, dimethylaniline from the dyestuffs industry, Tetryl manufacture was developed there and recommended for service use in 1910. Manufacture was restricted at Waltham Abbey to the North Site and an explanation of the manufacturing process can be found in RCHME (1993 p190-1).

12.3. T.N.T (2:4:6 - TRINITROTOLUENE)

Manufactured by the nitration of toluene, TNT was developed by Germany in 1902 and the 1914 - 18 war showed that the Germans had an insensitive replacement for Picric Acid in TNT, which could be poured into shells as its melting point was c. 80 degrees Celsius. These benefits were deemed worthwhile and it was discovered that Borneo Petroleum was a good source of toluene and available to the British Service.

Nitration involved high temperatures and very strong acids including oleum (sulphuric acid containing free sulphur trioxide). Some experimental manufacture and mixing of TNT, especially with RDX, was carried out in Area N after 1938, by which time a continuous process for manufacture had been developed. Amatols and Baratols are TNT mixtures with ammonium or barium nitrates.

12.4. BALLISTIC MODIFIERS

12.4.1. PICRITE (Nitroguanidine)

Not to be confused with Picric Acid or Picric Powder, Nitroguanidine was used at Waltham Abbey RGPF in the cordite matrix to reduce muzzle flash and is one of the ingredients in CORDITE 'N', 'NF' and 'MNF' (see 'Cordite' section).

12.4.2. LEAD SALTS

Lead salts came into use as ballistic modifiers with the solid rocket propellant programmes in the post 2nd World War development programmes. Manufactured in the eastern end of [G418] (T. Stemman pers. comm.), they were used in creating a flattening of the burning rate curve, an effect that creates a steady burning rate at a plateau, and known as 'platonisation'.

Manufacture was by precipitation of lead nitrate or acetate fed into a stirred reactor containing sodium stearate. The precipitate is filtered off, washed and dried before being added to the solid rocket propellant mix. No remains of this process have been found in [G418].

APPENDIX I

CATALOGUE

1 UNPUBLISHED SOURCES

2 PUBLISHED SOURCES

3 CARTOGRAPHIC REFERENCES

4 PLANS AND ELEVATIONS

5 SERVICES

6 DOCUMENTATION PACKS

7 BOX FILES

8 BUILDING PLAN BOOKS AND LISTS

9 PASSIVE AIR DEFENCE

10 PERIOD PLAN LIST

1.UNPUBLISHED SOURCES

Locations are given at the end of each reference in the following abbreviations;
WASC - The Waltham Abbey Special Collection at Epping Forest District Museum.
PRO - The Public Record Office at Kew.
CSL - The Chemical Society Library, London.
RJ - Restricted Journal.
OP - Out of print.

Where journals cannot be located at good university libraries the British Library is recommended, especially for those items now out of print

CRDD 1947 *The Chemical Research and Development Department 'Its Programme and Facilities'* Internal Report 21 May 1947 **WASC**

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Supply 5/760 1861-1904 Photograph Album - RGPF Explosions and Plant **PRO**

Supply 5/861 1903-1938 Photograph Album - RGPF Explosions and Plant **PRO**

Supply 5/862 1903-1930 Photograph Album - RGPF Various **PRO**

Supply 5/863 1940-1941 Photograph Album - Damage by Enemy Action **PRO**

WASC 1508 c.1945 RGPF Buildings Ledger **WASC**

WASC 1680 c.1925 RGPF Buildings Ledgerv **WASC**

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Where journals cannot be located at good university libraries the British Library is recommended, especially for those items now out of print

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3.CARTOGRAPHIC REFERENCES

Reference	Description	Scale	Date	Location
OS.1885	Ordnance Survey 1st Edition		**1885**	**ERO**
WASC 900/38	Quinton Hill Gun Cotton Factory Inset on North Site Map (1836 Corr.1888)	1:1250	**1888**	**NS**
Lord Sandhurst Report	Sandhurst Accident at Quinton Hill Report includes map of South Site.	1:2500	**1894**	**SS**
OS.1897	Ordnance Survey 2nd Edition	1:2500	**1897**	**SS**
WASC 900/62A	North and South Sites	1:2500	**1907/8**	**NS**
WASC 900/84	'ROYAL GUNPOWDER FACTORY, WALTHAM ABBEY' 13th Sept 1917, Revised March 1919, March 1923	1:2500	**1923**	**EFDM**
WASC 900/113	'PERME. WALTHAM ABBEY' April 1972 Revised 1976	1:2500	**1976**	**EFDM**
EAB/1	Copy of DRWG.No.1 included as part of EAB report (Ref : REP01)	1:2000	**1986**	**SS**
DRWG. No.1	R.O.F EXPLOSIVES DIVISION, WALTHAM ABBEY April 1983. Revised : Jan 1986, Feb 1987, June 1987, May 1988	1:2000	**1988**	**SS**

4.PLANS AND ELEVATIONS

BUILDINGS WITH NEW SERIES NUMBERS (BY AREAS)
REFERENCED BY CARD FILE FOR DRAWINGS (IN P754)
LOCATED IN LABELLED PLAN CHESTS HELD IN P754 ON South Site.

PLAN CHEST	DRAWER NUMBER	BUILDING NUMBERED DRAWINGS
5	1 2 3 4 5	Older, friable maps and plans. Older, friable maps and plans. G400 - 406 G407 - 420 G421 - 430
6	1 2 3 4	G431 G432 G432 G433 - 460
7	2 3 4 5	M300 - 342 M343 M343 M344 - 360

11	2 3 4 5	N500 - 530 N531 - 548 N549 N549
12	1 2 3 4 5	N550 N551 - 556 N557 - 563 N564 - 570 N571 - 600 + Derelict 1 & 2
13	1 2 3 4	R 641 - 660 R 661 - 670 R 671 - 680 R 681 - 691
14	2 3 4 5	P700 - 710 P711 - 716 P717 - 719 P720 - 725
15	1 2 3 4 5	P726 - 730 P731 - 740 P741 - 750 P751 - 755 P756 - 780
16	2 3 4 5	R600 - 610 R611 - 620 R621 - 630 R631 - 640

5.SERVICES

REFERENCED THROUGH CARD FILE FOR DRAWINGS

LOCATED IN LABELLED PLAN CHESTS IN P754 ON SOUTH SITE.

PLAN CHEST	DRAWER No.	DRAWING NUMBERS/DESCRIPTION
2	2 5	Telephones and Zones Fences and Bridges
5	2	G.B01 - G. SERVICES
6	5	M.B01-20 M. SERVICES
7	1	M.B21- M. SERVICES
11	1	N.B01- N.SERVICES
13	4	R.B01-B08 R.SERVICES
14	1	P.B01-B76 P. SERVICES
16	1	R.B01- R. SERVICES

20	4	SERVICES. MISCELLANEOUS

COVERAGE : Steam Pipes
Telephones
Canals
Tramways
Electricity
Fire Alarms
Street Lighting

6.DOCUMENTATION PACKS

Referenced through a List of 'Explosive Contaminated Buildings' (1990)

Located in files stored in unlabelled ECONO/STOR 203 boxes on dexian racking in P754 on SOUTH SITE.

CONTENT:

Each file contains : Location plan
Record drawing of building
Known history (limited)
Structural and/or services/utilities
Possible contaminants
Sample results
Details of contaminants
Decontamination procedure
Decontamination results
Decontamination certificate
Record photography (colour print)

7.R.O BOX FILES

Located in P754 on South Site

BFOOO	DESCRIPTION	DATE
BF001	Incident at N530	5 Jan 1989
BF002	Accident Reports from other Establishments	various
BF003*	Planning Permission Files on N521/M343 Also called D.O. 15	
BF004	Photographs, Films and Videos	
BF005	Photographs	

LIST : 9.11.89	Sheets 1-4 for Box Files in 21 (p754) Descriptions of contents Boxes DO1-18 DO1 : Drawing Registers DO2: Drawing Distribution DO3: Fire Hydrant Returns DO4: Card File : Hydrant Record Cards DO5: Logged Safety Information DO6: Logged Safety Audits DO7: Working File. Safety Audits DO8: Working File. Self Draining Showers DO9: COSHH DO10: Legionella DO11: O.S and Areas of Site DO12: Giltspur documents DO13: Miscellaneous Information DO14: M.D.O orders DO15: Planning Permission (see above*) DO16: Lonsdale 1985-1988 DO17: Fairhust De-com ++ DO18: Card File. A-Z Addresses	9.11.89 1985-1988

8.BUILDING PLAN BOOKS AND LISTS

Located in P754 on South Site.

BPB	Description	Date
01	Building Numbers and Use List	1981
02	Register of Plans, North Site (1 book)	1951
03	List of old and new numbers on 2 sheets of paper. North Site	
04	Book of Plan Numbers with building uses. North and South Site	pre 1925
05	Book of Building uses and old numbers	pre 1920
06	Book listing buildings used in R.D.X manufacture. Old and new numbers present	
07	Register of drawings. Alphabetical index. Old drawing number sequence	

08	Register of drawings. 1940, 1941, 1942, 1943, 1944, 1947, 1948, 1950, 1951, 1953	
09	Register of drawings (old numbers)	1850 - 1937
10	Book listing buildings uses by area. Floor areas and remarks. Grid reference from April 1983 map (E-35 etc.)	1985-6
EAB/2	List in REP01. Building Nos., uses, grid refs	1986
WASC 1506/1	Building Usage List. ERDE list of building numbers and functions	1972
11	North Site Building Use, Costs, Construction material	c 1988
12	South Site / Date of renovations and cost (Incl. ISRG list)	c 1988

9.PASSIVE AIR DEFENCE

Collection of Recording Sheets copied from Essex SMR and compiled by F. Nash in 1993.

Located at ERO.

Referenced by SMR Number e.g. : 10063 etc.

SMR. REF.	DESCRIPTION	DRAWING NO.1	NUMBER
10063	Standing. Telephone and line intact	E39	SS100
10064	Demolished. Slab remains	I38	SS126
10065	Standing	I36	P722a
10066	Not on site		
10067	Standing	K35	P722b
10068	Standing	M35	P722c
10069	Outside boundary fence	D35	SS127
10070	Standing	E33	SS 116
10071	Standing	I32	N586
10072	Outside boundary fence		

10073	Outside boundary fence		
10074	Demolished	L28	SS128

10.Period Plan List

Period	Date	Description Heading
I	pre 1887	Ordnance Survey 1st Edition copy
II	1887 - 1890	New NC Factory
III	1890's	New NG Factory
IV	1900 - 1913	Cordite MD Stoves &
V	1914 - 1918	1st WW further developments
VI	1919 - 1938	RDX
VII	1939 - 1945	None provided
VIII	1945 - 1991	Survey at 1:1250
VIII A	1945 - 1991	Project 1
VIII B	1945 - 1991	Project 2
VIII C	1945 - 1991	Project 3
VIII D	1945 - 1991	Ballistic Assessment

13.2 APPENDIX 2

PHOTOGRAPHIC REGISTER

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS1	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R688	N				
2	R688	SE				
3	R656	S				
4	R656	S				
5	R656	W				
6	R656	W				
7	R691	S				
8	R691	N				
9	R680	SW				
10	R680	SE				
11	R667	N				
12	R667	E				
13	R668	S				
14	R668	W				
15	R682	S				
16	R682	W				
17	R639/640	W				
18	R639/640	N				
19	R639/640	S				
20	R671	E				
21	R671	S				
22	R670 A & B	S				
23	R670 A & B	W				
24	R666	N				
25	R666	N				
26	R666	NE				
27	R669	N				
28	R669	W				
29	SS101	N				
30	SS101	E				
31	SS101	S				
32						
33						
34						
35						
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS2	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	OP 24 TELEPHONE CONN	E				
2	DITTO					
3	2" STEAM PIPE R688	NW				
4	SS 102 TANK BASE	W				
5	FIRE HYDRANT	SW				
6	R802					
7	R676	SW				
8	SS117	N				
9	SS117					
10	R657	NE				
11	SS123	S				
12	SS119	N				
13	SS118	NE				
14	SS504 6" MAIN	S				
15	8" MAIN					
16	TELEGRAPH POLE M349					
17	DITTO					
18	PIPE HANGER M349					
19	PIPE HANGER M349					
20	N547	N				
21	N547	SE				
22	N500	SE				
23	N500	NE				
24	N558	NW				
25	N558	SE				
26	N548	NW				
27	N548	SE				
28	N590	NE				
29	N590	NW				
30	WORKING SHOTS					
31						
32						
33						
34						
35						
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS3	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R684	W				Y
2	R684	N				Y
3	SS104	W				Y
4	SS104	N				Y
5	R683 (ENTRANCE)	E				Y
6	SS105	S				Y
7	R687	E				Y
8	R687	W				Y
9	R687	W				Y
10	SS106	W				Y
11	SS106	N				Y
12	SS107	W				Y
13	SS107	N				Y
14	R693-4-5 (BASES ONLY)	N				Y
15	R696 (BASES ONLY)	W				Y
16	R662	N				Y
17	R662	E				Y
18	R676	W				Y
19	R676	N				Y
20	R673	S				Y
21	R673	E				Y
22	R653	E				Y
23	R653	S				Y
24	R642	S				Y
25	R642	NE				Y
26	R642	NW				Y
27	R652 (PLANT ROOM)	N				Y
28	R652	W				Y
29	R652	E				Y
30	R652	S				Y
31	R677	S				Y
32	R677	W				Y
33	R643 (BASE)	W				Y
34	R699 (BASE)	S				Y
35						Y
36						Y

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS4	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R690	S				Y
2	R690	W				Y
3	R672	W				Y
4	R672	E				Y
5	R641	S				Y
6	R641 (INTERNAL)					N
7	R677	S				Y
8	R677	E				Y
9	R664	NE				Y
10	R664	E				Y
11	R675	W				Y
12	R675	N				Y
13	R663 (EXTENSION)	N				Y
14	R663 (EXTENSION)	E				Y
15	R663	N				Y
16	R663	N				Y
17	R663	SW				Y
18	R698	E				Y
19	R698	N				Y
20	R665	W				Y
21	R665	N				Y
22	R679	N				Y
23	R679	W				Y
24	R678	E				Y
25	R678	N				Y
26	R652 (INTERNAL-TANK)					Y
27	R652 (INTERNAL-TANK)					Y
28	R652 (INTERNAL-TANK)					Y
29	TANK SUPPORTS SS NO ?	W				Y
30	TANK SUPPORTS SS NO ?	N				Y
31	BARRIER	N				Y
32	BARRIER	S				Y
33						
34						
35						
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS5	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R676 (INTERNAL)					Y
2	R676 (INTERNAL)					Y
3	R676 (INTERNAL)					Y
4	N524	E				Y
5	N524	E				Y
6	G454	N				Y
7	G454	E				Y
8	N519	N				Y
9	N519	E				Y
10	N522/523	E				Y
11	N522	NE				Y
12	N523	SE				Y
13	N527	S				Y
14	N527	W				Y
15	N528	E				Y
16	N528	S				Y
17	N529	W				Y
18	N529	S				Y
19	N530 ENTRANCE	E				Y
20	N530 (SITE OF)	N				Y
21	N534	E				Y
22	N534	S				Y
23	N534	NW				Y
24	N531	W				Y
25	P722	S				Y
26	P722	E				Y
27	P768	S				Y
28	P768	W				Y
29	P724	S				Y
30	P724	W				Y
31	P729 (ENTRANCE)	S				Y
32	P774	S				Y
33	P750	S				Y
34	P750	W				Y
35						
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS6	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P723	W				Y
2						Y
3	P723	W				Y
4	P738	S				Y
5						Y
6	P728	W				Y
7						Y
8	P727	E				Y
9						Y
10	P727	S				Y
11	P726	S				Y
12	P726	W				Y
13	P725	S				Y
14	P735	N				Y
15	P725	W				Y
16						Y
17	P770	W				Y
18						Y
19						Y
20	P770	S				Y
21	P756	S				Y
22	P756	E				Y
23	P719	S				Y
24	P719	W				Y
25	P719 ROOF	SE				Y
26						Y
27	MARLEY PREFAB ROOF					Y
28						Y
29	P764	E				Y
30	P764	SE				Y
31	P765	SE				Y
32	P765	NE				Y
33	P758	W				Y
34	P758	N				Y
35	P758	E				Y
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS7	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P766	S				Y
2	P766	E				Y
3	P759	S				Y
4	P759	NW				Y
5	P757	E				Y
6	P757	W				Y
7	P720 (ENTRANCE)	E				Y
8	P720	W				Y
9	P720 ROOF	SE				Y
10	P721	W				Y
11	P721	NW				Y
12	2 LEG LIGHT COVER	W				Y
13	2 LEG LIGHT COVER	S				Y
14	P761 (BASE)	W				Y
15	W OF 761 ?	N				Y
16	P763	E				Y
17	P763	SW				Y
18	P751	N				Y
19	P751	SW				Y
20	P752	E				Y
21	P752	N				Y
22	SS113	N				Y
23	SS114	N				Y
24	SS114	S				Y
25	P741 SHOE COVER		250mm			Y
26	P741 INGOT BOXES					Y
27	P741 SCALES		250mm			Y
28	P741 (ENTRANCE)	S				Y
29	P741	SW				Y
30	P748	N				Y
31	P748	SE				Y
32	P749	S				Y
33	P749	W				Y
34	P747	E				Y
35	P747	N				Y
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS8	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P727 PIT	W				Y
2	P727 BENCHMASTER M/C	S	250mm			Y
3	P727 CLAMP	E	250mm			Y
4	P727 NOTICE BOARD	E	250mm			Y
5	P727 CONTROL PANEL	S	250mm			Y
6	P727 BUTLER SINK	N	250mm			Y
7	P726 PUMP MOTOR	E	250mm			Y
8	P726 PRESSURE GUAGE	N	250mm			Y
9	P725 BLAST DOOR	E				Y
10	P725 FIRING BED	E				Y
11	P725 TARGET	W				Y
12	P718	S				Y
13	P718	E				Y
14	P718 (ENTRANCE)	E				Y
15	P745	S				Y
16	P717	W				Y
17						Y
18	P717	E				Y
19	P716	S				Y
20	P716	W				Y
21	P716	S				Y
22	P706	N				Y
23	P706	W				Y
24	P705	NE				Y
25	P705	NW				Y
26	P704	NE				Y
27	P704	S				Y
28	P773	NW				Y
29	P773	SW				Y
30	P773 SAFE ?	SE				Y
31	P702	E				Y
32	P702	N				Y
33	P762	W				Y
34	P762	N				Y
35	P775 (BASE ONLY)	S				Y
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS9	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P744	W				Y
2	P744	S				Y
3	P703	SW				Y
4	P703	SE				Y
5	P703	E				Y
6	P769	SE				Y
7	P769	NW				Y
8	P701	NE				Y
9	P701	E				Y
10	P700	N				Y
11	P700	W				Y
12	P777	S				Y
13	P777	SE				Y
14	P754	S				Y
15	P754	N				Y
16	P746	NE				Y
17	P746	E				Y
18	P754	NW				Y
19	P743	N				Y
20	P743	NE				Y
21	P742	SE				Y
22	P730	W				Y
23	P730	S				Y
24	P731	S				Y
25	P731	W				Y
26	P707	S				Y
27	P707	NE				Y
28	P771	NE				Y
29	P708	NW				Y
30	P708	NE				Y
31	P708	SE				Y
32	P772	SW				Y
33	P772	E				Y
34	P772	W				Y
35						
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS10	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P714	S				Y
2	P740	S				Y
3	P740	S				Y
4	P740	W				Y
5	P740	N				Y
6	P714	NW				Y
7	P709	S				Y
8	P709	SE				Y
9	P713	E				Y
10	P713	S				Y
11	P712	SW				Y
12	P712	W				Y
13	P710	N				Y
14	P710	NW				Y
15	R600	W				Y
16	R686	W				Y
17	R686	S				Y
18	P718 TANGYE PRESS					Y
19	P718 CLEAN CUPBOARDS		250MM			Y
20	P718 ROPE MATTING		250MM			Y
21	P718 SMALL TANGYE PRESS		250MM			Y
22	P718 SAFETY LIGHT					Y
23	P758 DEHUMIDIFIER		250MM			Y
24	P758 CONTROL PANEL		250MM			Y
25	P758 COPPER VAULTS					Y
26	P761	S				Y
27	P720 STRAND BAY M/C		250MM			Y
28	P720 PRESSURE GUAGES		250MM			Y
29	P739	SE				Y
30	P737	S				Y
31	P737 ROOF	SE				Y
32	P736	N				Y
33	P715	S				Y
34	P715	N				Y
35	P738	S				Y
36						

X

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS11	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P735 ENTRANCE	E				Y
2	P733/734 ENTRANCE	E				Y
3	P732	E				Y
4	P732-3-4-5	W				Y
5	N531	W				Y
6	N531	SW				Y
7	N531	N				Y
8	N532	W				Y
9	N535	N				Y
10	N536	N				Y
11	N542	N				Y
12	N535-6	E				Y
13	N540	SE				Y
14	N540	W				Y
15	N537	N				Y
16	N538	NE				Y
17	N592-3-4-5 SITE OF	W				Y
18	N551	E				Y
19	N539	SW				Y
20	N538	SW				Y
21	N537	SW				Y
22	G445	NW				Y
23	G445	NE				Y
24	G444	N				Y
25	G444	NE				Y
26	G440	N				Y
27	G440	NE				Y
28	G440	N				Y
29	G440	E				Y
30	G456	W				Y
31	G456	N				Y
32	G457	N				Y
33	G457	NE				Y
34	G459	N				Y
35	G459	NE				Y
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS12	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	G458	N				Y
2	G458	W				Y
3	G441	S				Y
4	G441	W				Y
5	G441	N				Y
6	N513	S				Y
7	N513	SW				Y
8	G431	N				Y
9	G431	W				Y
10	G431	NW				Y
11	G431	E				Y
12	G421	N				Y
13	G432	SW				Y
14	G432	NW				Y
15	N509	SW				Y
16	N509	E				Y
17	G430	N				Y
18	G430	NW				Y
19	N506	S				Y
20	N505	S				Y
21	N505	E				Y
22	G429	S				Y
23	G424	S				Y
24	G424	NE				Y
25	G417	E				Y
26	G428	E				Y
27	G418	SW				Y
28	G418	N				Y
29	G415	W				Y
30	G415	N				Y
31	G411	NE				Y
32	G411	E				Y
33	G435 & G420	N				Y
34	G413	SW				Y
35	G413	NW				Y
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS13	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	G437	NW				Y
2	G437	S				Y
3						
4	G414	N				Y
5	G436	W				Y
6	G406	SW				Y
7	G42? DEISEL TANKS	SE				Y
8	G404 GASOMETER	NW				Y
9	G405	N				Y
10	G405	NW				Y
11	G400	W				Y
12	G400	NW				Y
13	G402	N				Y
14	G402	NE				Y
15	G403	NE				Y
16	G403	NW				Y
17	G412	NW				Y
18	G408	NE				Y
19	G408	SE				Y
20	G407	E				Y
21	G407	NW				Y
22	G409	W				Y
23	M455	SE				Y
24	M332	SW				Y
25	M354	S				Y
26	M354	W				Y
27	BIKE SHED	SE				Y
28	M327	SE				Y
29	M329	NW				Y
30	M329	S				Y
31	M331/333	S				Y
32	M330	SE				Y
33	M328	NE				Y
34	M333	S				Y
35						
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS14	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	N582	NW				Y
2	N582	W				Y
3	N584	N				Y
4	N584	E				Y
5	N554	NE				Y
6	N554	S				Y
7	N589	S				Y
8	N589	N				Y
9	N559-60-61 SITE OF	SE				Y
10	N571	W				Y
11	N571	E				Y
12	N550	NW				Y
13	N550	SW				Y
14	N550	E				Y
15	N545	SW				Y
16	N545	E				Y
17	N557	SW				Y
18	N557	NW				Y
19	N557 ANNEXE	W				Y
20	N556	S				Y
21	N556	W				Y
22	N558	N				Y
23	N553	NW				Y
24	N553	N				Y
25	N557	S				Y
26	N583	SE				Y
27	N585	NE				Y
28	N588	S				Y
29	N588	SW				Y
30	N557	SE				Y
31	STEAM ENGINE CHASSIS N554	E				Y
32	N566	N				Y
33	N566	SE				Y
34	N569	NW				Y
35	N569	SW				Y
36						

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FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS15	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	N580	N				Y
2	N580	S				Y
3	N549	E				Y
4	N549	E				Y
5	N546	N				Y
6	N586	NW				Y
7	N586	NE				Y
8	N547	N				Y
9	N547	NE				Y
10	N581	S				Y
11	N579	S				Y
12	N579	SW				Y
13	N574	W				Y
14	N574	N				Y
15	N577	E				Y
16	N577	S				Y
17	N573	SW				Y
18	N???	NW				Y
19	N572	W				Y
20	N568	SE				Y
21	N567	E				Y
22	N567	NE				Y
23	N562	E				Y
24	N562	SE				Y
25	N562	NE				Y
26	N652	W				Y
27	N564	W				Y
28	N564	S				Y
29	N564	SE				Y
30	N552	E				Y
31	N552	NW				Y
32	N551	SW				Y
33	N551	S				Y
34	N551	SE				Y
35	N550 & 554 GEN	N				Y
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS16	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	N570	SW				Y
2	N570	E				Y
3	M357	N				Y
4	M357	NE				Y
5	M356	NW				Y
6	M356	NE				Y
7	M358 & M346	NE				Y
8	M343	SW				Y
9	M343	SE				Y
10	M335	NW				Y
11	M334	N				Y
12	M339	NW				Y
13	M338	NW				Y
14	M340	S				Y
15	M340	SE				Y
16	M358	S				Y
17	M358	SW				Y
18	M360	S				Y
19	M361	SE				Y
20	M343 SIGN	N				Y
21	M342	SW				Y
22	M349	NW				Y
23	M349	NE				Y
24	R661	W				Y
25	R661	N				Y
26	R660	N				Y
27	R659	N				Y
28	EMERGENCY TEL BOX	NE				Y
29	R658	N				Y
30	R658	SW				Y
31	R658	SE				Y
32	R658	NE				Y
33	R658 WINDOW	E				Y
34	R658 RADIATOR	E				Y
35						
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS17	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R657	S				Y
2	R655	NE				Y
3	R655	NW				Y
4	R655					Y
5	R654	SE				Y
6	EMERG TEL BOX	S				Y
7	R651	SW				Y
8	R650	SE				Y
9	R650	SW				Y
10	R649	SE				Y
11	R649	SW				Y
12	R631	SW				Y
13	R631	SE				Y
14	R632	SW				Y
15	R632	SE				Y
16	R633	W				Y
17	R681	N				Y
18	R681	E				Y
19	R634	N				Y
20	R634	NW				Y
21	R638	W				Y
22	R638	S				Y
23	R685	SW				Y
24	R635	SW				Y
25	R635	NE				Y
26	R636	SW				Y
27	R644	NE				Y
28	R646	NW				Y
29	R645	S				Y
30	R628	NW				Y
31	R627	NW				Y
32	R626	NW				Y
33	R625	NW				Y
34	R624	NW				Y
35	R627	NE				Y
36	R626	W				Y

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS18	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R600	E				Y
2	SS115	N				Y
3	R614	S				Y
4	R614	W				Y
5	R614	NW				Y
6	R601	W				Y
7	R601	NW				Y
8	R602	NW				Y
9	R603	W				Y
10	R603	N				Y
11	R604 SITE OF	N				Y
12	R605 SITE OF	N				Y
13	R606 SITE OF	N				Y
14	R607 SITE OF	NW				Y
15	PILL BOX ADJ R607	W				Y
16	R608	NE				Y
17	R620	SW				Y
18	R619	SE				Y
19	R609 SITE OF	N				Y
20	R618	SW				Y
21	R617	SW				Y
22	R616	W				Y
23	R616	S				Y
24	R615	E				Y
25	R615	SE				Y
26	R637	W				Y
27	R613 SITE OF	NE				Y
28	R612	NW				Y
29	R612	SW				Y
30	R611	E				Y
31	R610	NE				Y
32	R648	NW				Y
33	R647	NW				Y
34						
35						
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS19	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R622	NE				
2	R623	NW				
3	R621	N				
4	R621	E				
5	M316	W				
6	M316	NW				
7	M319	SE				
8	M319	S				
9	M317	S				
10	M317	SE				
11	M321	SE				
12	M321	NE				
13	M322	N				
14	M322	W				
15	M320	SW				
16	M323	E				
17	M342	SE				
18	M353	SE				
19	M353	NE				
20	M352	E				
21	N514	S				
22	M351	N				
23	M329	NE				
24	M329	S				
25	M329	E				
26	M329	S				
27	M329	SW				
28	G418	N				
29	G418	N				
30	G418	W				
31	G418	W				
32	G418	E				
33	G418	SE				
34	G418	N				
35	PIPES	W				
36	PIPE CONTROLS	S				

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS20	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	N550 COMPLEX	N				
2	P722C	SE				
3	P781	N				
4	P745	E				
5	P718	N				
6	P703	E				
7	P703 SHOE LOCKER	N				
8	P703 TROLLEY	N				
9	R636 DOORS	S				
10	STEEL BLAST WALL	N				
11	G401	SW				
12	G401	W				
13	G451	NW				
14	G451	W				
15	SS552	SE				
16	SS552	S				
17	SS553	S				
18	SS553	E				
19	SS553	E				
20	SS553	SE				
21	SS554	S				
22	SS554	NW				
23	SS554	W				
24	SS555	S				
25	SS558	S				
26	SS558	NW				
27	SS556	N				
28	BETWEEN 558 & 556	N				
29	BETWEEN 558 & 556	NW				
30	SS108	S				
31	RANGE SIGN	SW				
32	R689	S				
33						
34						
35						
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS21	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	SS557	SW				
2	SS557	W				
3	P722C	E				
4	SS504	SW				
5	SS553	SW				
6	SS553	SE				
7	SS553	E				
8	SS562	NW				
9	SS562	SW				
10	M COMPLEX	W				
11	SS209 SS211 SS213	W				
12	SS209 SS211 SS213	NW				
13	M348 MACHINE					
14	M348 SHOE LOCKER					
15	M348 HIDE FLOOR					
16	M COMPLEX	NE				
17	CONTRABAND SIGN	S				
18	GRINDING STONES	N				
19	GRINDING STONES	W				
20	HORSES					
21	N535 SHORING	NW				
22	N536 ALARM TRIANGLE	W				
23	N535 ELECTRIC BOX					
24	N535/6 SHORING	W				
25	N539	N				
26	N540	W				
27	N550	SE				
28	N531	W				
29	N531 WINCH	N				
30	G440	N				
31	N531`	E				
32						
33						
34						
35						
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WS22	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	N532	W				
2	N531	E				
3	N531 LIFT SHAFT	SE				
4	N531 WINCH					
5	P ENTRANCE AREA	W				
6	P ENTRANCE AREA	NW				
7	P ENTRANCE AREA	SW				
8	G451 M/C	N				
9	G451 M/C	N				
10	SS218	NW				
11	M344	SW				
12	M344	W				
13	M345	NE				
14	M345	S				
15	M340	S				
16	SS217	SE				
17	M325	S				
18	M338	N				
19	SS221	S				
20	M338	NW				
21	M351	S				
22	SS216	E				
23	M351	W				
24	P760	NW				
25	P755	SW				
26	P753	W				
27	G412	SW				
28	G433	SW				
29	G446	E				
30	SS122	W				
31	N505	NE				
32	ELLEN WORKING					
33						
34						
35						
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM101	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R688	N				
2	R688	SE				
3	R656	S				
4	R656	S				
5	R656	W				
6	R656	W				
7	R691	S				
8	R691	N				
9	R680	SW				
10	R680	SE				
11	R667	N				
12	R667	E				
13	R668	S				
14	R668	W				
15	R682	S				
16	R682	W				
17	R639/640	W				
18	R639/640	N				
19	R639/640	S				
20	R671	E				
21	R671	S				
22	R670 A & B	S				
23	R670 A & B	W				
24	R666	N				
25	R666	N				
26	R666	NE				
27	R669	N				
28	R669	W				
29	SS101	N				
30	SS101	E				
31						
32						
33						
34						
35						
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM102	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	OP 24 TELEPHONE CONN	E				
2	DITTO					
3	2" STEAM PIPE R688	NW				
4	SS 102 TANK BASE	W				
5						
6	FIRE HYDRANT	SW				
7	R802					
8	R676	SW				
9	SS117	N				
10	SS123	N				
11	SS119	NE				
12	SS118	S				
13	6" MAIN	S				
14	DITTO	SE				
15	8" MAIN					
16	TELEPHONE POLE M349					
17	TELEGRAPH POLE M349					
18	PIPE HANGER M349					
19	PIPE HANGER M349					
20	N547	N				
21	N547	SE				
22	N500	SE				
23	N500	SE				
24	N555	NE				
25	N555	SW				
26	N548	NE				
27	N548	SW				
28	N590	NE				
29	N590	NW				
30	N590	NW				
30	WORKING SHOTS					
31						
32						
33						
34						
35						
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM103	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R684	W				Y
2	R684	N				Y
3	SS104	W				Y
4	SS104	N				Y
5	R683 (ENTRANCE)	E				Y
6	SS105	S				Y
7	R687	E				Y
8	R687	W				Y
9	R687	W				Y
10	SS106	W				Y
11	SS106	N				Y
12	SS107	W				Y
13	SS107	N				Y
14	R693-4-5 (BASES ONLY)	N				Y
15	R696 (BASES ONLY)	W				Y
16	R662	N				Y
17	R662	E				Y
18	R676	W				Y
19	R676	N				Y
20	R673	S				Y
21	R673	E				Y
22	R653	E				Y
23	R653	S				Y
24	R642	S				Y
25	R642	NE				Y
26	R642	NW				Y
27	R652 (PLANT ROOM)	N				Y
28	R652	W				Y
29	R652	E				Y
30	R652	S				Y
31	R677	S				Y
32	R677	W				Y
33	R643 (BASE)	W				Y
34	R699 (BASE)	S				Y
35						Y
36						Y

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM104	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R690	S				Y
2	R690	W				Y
3	R672	W				Y
4	R672	E				Y
5	R641	S				Y
6	R641 (INTERNAL)					Y
7	R677	S				Y
8	R677	E				Y
9	R664	NE				Y
10	R664	E				Y
11	R675	W				Y
12	R675	N				Y
13	R663 (EXTENSION)	N				Y
14	R663 (EXTENSION)	E				Y
15	R663	N				Y
16	R663	N				Y
17	R663	SW				Y
18	R698	E				Y
19	R698	N				Y
20	R665	W				Y
21	R665	N				Y
22	R679	N				Y
23	R679	W				Y
24	R678	E				Y
25	R678	N				Y
26	R652 (INTERNAL-TANK)					Y
27	R652 (INTERNAL-TANK)					Y
28	R652 (INTERNAL-TANK)					Y
29	TANK SUPPORTS SS NO ?	W				Y
30	TANK SUPPORTS SS NO ?	N				Y
31	BARRIER	N				Y
32	BARRIER	S				Y
33						
34						
35						
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM105	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R676 (INTERNAL)					Y
2	R676 (INTERNAL)					Y
3	R676 (INTERNAL)					Y
4	N524	E				Y
5	N524	E				Y
6	G454	N				Y
7	G454	E				Y
8	N519	N				Y
9	N519	E				Y
10	N522/523	E				Y
11	N522	NE				Y
12	N523	SE				Y
13	N527	S				Y
14	N527	W				Y
15	N528	E				Y
16	N528	S				Y
17	N529	W				Y
18	N529	S				Y
19	N530 ENTRANCE	E				Y
20	N530 (SITE OF)	N				Y
21	N534	E				Y
22	N534	S				Y
23	N534	NW				Y
24	N531	W				Y
25	P722	S				Y
26	P722	E				Y
27	P768	S				Y
28	P768	W				Y
29	P724	S				Y
30	P724	W				Y
31	P729 (ENTRANCE)	S				Y
32	P774	S				Y
33	P750	S				Y
34	P750	W				Y
35						
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM106	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P723	W				Y
2	P723	W				Y
3	P728	S				Y
4	P728	W				Y
5	P727	E				Y
6	P727	S				Y
7	P726	S				Y
8	P726	W				Y
9	P725	S				Y
10	P725	N				Y
11	P725	W				Y
12	P770	W				Y
13	P770	S				Y
14	P756	S				Y
15	P756	E				Y
16	P719	S				Y
17	P719	W				Y
18	P719 ROOF	SE				Y
19	MARLEY PRE-FAB ROOF					Y
20	P764	E				Y
21	P764	SE				Y
22	P765	SE				Y
23	P765	NE				Y
24	P758	W				Y
25	P758	E				Y
26	P758	NE				Y
27						
28						
29						
30						
31						
32						
33						
34						
35						
36						

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SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM107	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P766	S				Y
2	P766	E				Y
3	P759	S				Y
4	P759	NW				Y
5	P757	E				Y
6	P757	W				Y
7	P720 (ENTRANCE)	E				Y
8	P720	W				Y
9	P720 ROOF	SE				Y
10	P721	W				Y
11	P721	NW				Y
12	2 LEG LIGHT COVER	W				Y
13	2 LEG LIGHT COVER	S				Y
14	P761 (BASE)	W				Y
15	W OF 761 ?	N				Y
16	P763	E				Y
17	P763	SW				Y
18	P751	N				Y
19	P751	SW				Y
20	P752	E				Y
21	P752	N				Y
22	SS113	N				Y
23	SS114	N				Y
24	SS114	S				Y
25	P741 SHOE COVER		250mm			Y
26	P741 INGOT BOXES					Y
27	P741 SCALES		250mm			Y
28	P741 (ENTRANCE)	S				Y
29	P741	SW				Y
30	P748	N				Y
31	P748	SE				Y
32	P749	S				Y
33	P749	W				Y
34	P747	E				Y
35	P747	N				Y
36						

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FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM108	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P727 PIT	W				Y
2	P727 BENCHMASTER M/C	S	250mm			Y
3	P727 CLAMP	E	250mm			Y
4	P727 NOTICE BOARD	E	250mm			Y
5	P727 CONTROL PANEL	S	250mm			Y
6	P727 BUTLER SINK	N	250mm			Y
7	P726 PUMP MOTOR	E	250mm			Y
8	P726 PRESSURE GUAGE	N	250mm			Y
9	P725 BLAST DOOR	E				Y
10	P725 FIRING BED	E				Y
11	P725 TARGET	W				Y
12	P718	S				Y
13	P718	E				Y
14	P718 (ENTRANCE)	E				Y
15	P745	S				Y
16	P717	W				Y
17						Y
18	P717	E				Y
19	P716	S				Y
20	P716	W				Y
21	P716	S				Y
22	P706	N				Y
23	P706	W				Y
24	P705	NE				Y
25	P705	NW				Y
26	P704	NE				Y
27	P704	S				Y
28	P773	NW				Y
29	P773	SW				Y
30	P773 SAFE ?	SE				Y
31	P702	E				Y
32	P702	N				Y
33	P762	W				Y
34	P762	N				Y
35	P775 (BASE ONLY)	S				Y
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM109	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P744	W				Y
2	P744	S				Y
3	P703	SW				Y
4	P703	SE				Y
5	P703	E				Y
6	P769	SE				Y
7	P769	NW				Y
8	P701	NE				Y
9	P701	E				Y
10	P700	N				Y
11	P700	W				Y
12	P777	S				Y
13	P777	SE				Y
14	P754	S				Y
15	P754	N				Y
16	P746	NE				Y
17	P746	E				Y
18	P754	NW				Y
19	P743	N				Y
20	P743	NE				Y
21	P742	SE				Y
22	P730	W				Y
23	P730	S				Y
24	P731	S				Y
25	P731	W				Y
26	P707	S				Y
27	P707	NE				Y
28	P771	NE				Y
29	P708	NW				Y
30	P708	NE				Y
31	P708	SE				Y
32	P772	SW				Y
33	P772	E				Y
34	P772	W				Y
35						
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM110	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P714	S				Y
2	P740	S				Y
3	P740	S				Y
4	P740	W				Y
5	P740	N				Y
6	P714	NW				Y
7	P709	S				Y
8	P709	SE				Y
9	P713	E				Y
10	P713	S				Y
11	P712	SW				Y
12	P712	W				Y
13	P710	N				Y
14	P710	NW				Y
15	R600	W				Y
16	R686	W				Y
17	R686	S				Y
18	P718 TANGYE PRESS					Y
19	P718 CLEAN CUPBOARDS		250MM			Y
20	P718 ROPE MATTING		250MM			Y
21	P718 SMALL TANGYE PRESS		250MM			Y
22	P718 SAFETY LIGHT					Y
23	P758 DEHUMIDIFIER		250MM			Y
24	P758 CONTROL PANEL		250MM			Y
25	P758 COPPER VAULTS					Y
26	P761	S				Y
27	P720 STRAND BAY M/C		250MM			Y
28	P720 PRESSURE GUAGES		250MM			Y
29	P739	SE				Y
30	P737	S				Y
31	P737 ROOF	SE				Y
32	P736	N				Y
33	P715	S				Y
34	P715	N				Y
35	P738	S				Y
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM111	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	P735 ENTRANCE	E				Y
2	P733/734 ENTRANCE	E				Y
3	P732	E				Y
4	P732-3-4-5	W				Y
5	N531	W				Y
6	N531	SW				Y
7	N531	N				Y
8	N532	W				Y
9	N535	N				Y
10	N536	N				Y
11	N542	N				Y
12	N535-6	E				Y
13	N540	SE				Y
14	N540	W				Y
15	N537	N				Y
16	N538	NE				Y
17	N592-3-4-5 SITE OF	W				Y
18	N551	E				Y
19	N539	SW				Y
20	N538	SW				Y
21	N537	SW				Y
22	G445	NW				Y
23	G445	NE				Y
24	G444	N				Y
25	G444	NE				Y
26	G440	N				Y
27	G440	NE				Y
28	G440	N				Y
29	G440	E				Y
30	G456	W				Y
31	G456	N				Y
32	G457	N				Y
33	G457	NE				Y
34	G459	N				Y
35	G459	NE				Y
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM112	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	G458	N				Y
2	G458	W				Y
3	G441	S				Y
4	G441	W				Y
5	G441	N				Y
6	N513	S				Y
7	N513	SW				Y
8	G431	N				Y
9	G431	W				Y
10	G431	NW				Y
11	G431	E				Y
12	G421	N				Y
13	G432	SW				Y
14	G432	NW				Y
15	N509	SW				Y
16	N509	E				Y
17	G430	N				Y
18	G430	NW				Y
19	N506	S				Y
20	N505	S				Y
21	N505	E				Y
22	G429	S				Y
23	G424	S				Y
24	G424	NE				Y
25	G417	E				Y
26	G428	E				Y
27	G418	SW				Y
28	G418	N				Y
29	G415	W				Y
30	G415	N				Y
31	G411	NE				Y
32	G411	E				Y
33	G435 & G420	N				Y
34	G413	SW				Y
35	G413	NW				Y
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM113	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	G437	NW				Y
2	G437	S				Y
3	G414	N				Y
4	G436	W				Y
5	G406	SW				Y
6	G42? DEISEL TANKS	SE				Y
7	G404 GASOMETER	NW				Y
8	G405	N				Y
9	G405	NW				Y
10	G400	W				Y
11	G400	NW				Y
12	G402	N				Y
13	G402	NE				Y
14	G403	NE				Y
15	G403	NW				Y
16	G412	NW				Y
17	G408	NE				Y
18	G408	SE				Y
19	G407	E				Y
20	G407	NW				Y
21	G409	W				Y
22	M455	SE				Y
23	M332	SW				Y
24	M354	S				Y
25	M354	W				Y
26	BIKE SHED	SE				Y
27	M327	SE				Y
28	M329	NW				Y
29	M329	S				Y
30	M331/333	S				Y
31	M330	SE				Y
32	M328	NE				Y
33	M333	S				Y
34						
35						
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM114	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	N582	NW				Y
2	N582	W				Y
3	N584	N				Y
4	N584	E				Y
5	N554	NE				Y
6	N554	S				Y
7	N589	S				Y
8	N589	N				Y
9	N559-60-61 SITE OF	SE				Y
10	N571	W				Y
11	N571	E				Y
12	N550	NW				Y
13	N550	SW				Y
14	N550	E				Y
15	N545	SW				Y
16	N545	E				Y
17	N557	SW				Y
18	N557	NW				Y
19	N557 ANNEXE	W				Y
20	N556	S				Y
21	N556	W				Y
22	N558	N				Y
23	N553	NW				Y
24	N553	N				Y
25	N557	S				Y
26	N583	SE				Y
27	N585	NE				Y
28	N588	S				Y
29	N588	SW				Y
30	N557	SE				Y
31	STEAM ENGINE CHASSIS N554	E				Y
32	N566	N				Y
33	N566	SE				Y
34	N569	NW				Y
35	N569	SW				Y
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM115	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	N580	N				Y
2	N580	S				Y
3	N549	E				Y
4	N549	E				Y
5	N546	N				Y
6	N586	NW				Y
7	N586	NE				Y
8	N547	N				Y
9	N547	NE				Y
10	N581	S				Y
11	N579	S				Y
12	N579	SW				Y
13	N574	W				Y
14	N574	N				Y
15	N577	E				Y
16	N577	S				Y
17	N573	SW				Y
18	N???	NW				Y
19	N572	W				Y
20	N568	SE				Y
21	N567	E				Y
22	N567	NE				Y
23	N562	E				Y
24	N562	SE				Y
25	N562	NE				Y
26	N652	W				Y
27	N564	W				Y
28	N564	S				Y
29	N564	SE				Y
30	N552	E				Y
31	N552	NW				Y
32	N551	SW				Y
33	N551	S				Y
34	N551	SE				Y
35	N550 & 554 GEN	N				Y
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM116	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	N570	SW				Y
2	N570	E				Y
3	M357	N				Y
4	M357	NE				Y
5	M356	NW				Y
6	M356	NE				Y
7	M358 & M346	NE				Y
8	M343	SW				Y
9	M343	SE				Y
10	M335	NW				Y
11	M334	N				Y
12	M339	NW				Y
13	M338	NW				Y
14	M340	S				Y
15	M340	SE				Y
16	M358	S				Y
17	M358	SW				Y
18	M360	S				Y
19	M361	SE				Y
20	M343 SIGN	N				Y
21	M342	SW				Y
22	M349	NW				Y
23	M349	NE				Y
24	R661	W				Y
25	R661	N				Y
26	R660	N				Y
27	R659	N				Y
28	EMERGENCY TEL BOX	NE				Y
29	R658	N				Y
30	R658	SW				Y
31	R658	SE				Y
32	R658	NE				Y
33	R658 WINDOW	E				Y
34	R658 RADIATOR	E				Y
35						
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM117	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R657	S				Y
2	R655	NE				Y
3	R655	NW				Y
4	R655					Y
5	R654	SE				Y
6	EMERG TEL BOX	S				Y
7	R651	SW				Y
8	R650	SE				Y
9	R650	SW				Y
10	R649	SE				Y
11	R649	SW				Y
12	R631	SW				Y
13	R631	SE				Y
14	R632	SW				Y
15	R632	SE				Y
16	R633	W				Y
17	R681	N				Y
18	R681	E				Y
19	R634	N				Y
20	R634	NW				Y
21	R638	W				Y
22	R638	S				Y
23	R685	SW				Y
24	R635	SW				Y
25	R635	NE				Y
26	R636	SW				Y
27	R644	NE				Y
28	R646	NW				Y
29	R645	S				Y
30	R628	NW				Y
31	R627	NW				Y
32	R626	NW				Y
33	R625	NW				Y
34	R624	NW				Y
35	R627	NE				Y
36	R626	W				Y

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM118	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R600	E				Y
2	SS115	N				Y
3	R614	S				Y
4	R614	W				Y
5	R614	NW				Y
6	R601	W				Y
7	R601	NW				Y
8	R602	NW				Y
9	R603	W				Y
10	R603	N				Y
11	R604 SITE OF	N				Y
12	R605 SITE OF	N				Y
13	R606 SITE OF	N				Y
14	R607 SITE OF	NW				Y
15	PILL BOX ADJ R607	W				Y
16	R608	NE				Y
17	R620	SW				Y
18	R619	SE				Y
19	R609 SITE OF	N				Y
20	R618	SW				Y
21	R617	SW				Y
22	R616	W				Y
23	R616	S				Y
24	R615	E				Y
25	R615	SE				Y
26	R637	W				Y
27	R613 SITE OF	NE				Y
28	R612	NW				Y
29	R612	SW				Y
30	R611	E				Y
31	R610	NE				Y
32	R648	NW				Y
33	R647	NW				Y
34						
35						
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM119	200	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	R622	NE				
2	R623	NW				
3	R621	N				
4	R621	E				
5	M316	W				
6	M316	NW				
7	M319	SE				
8	M319	S				
9	M317	S				
10	M317	SE				
11	M321	SE				
12	M321	NE				
13	M322	N				
14	M322	W				
15	M320	SW				
16	M323	E				
17	M342	SE				
18	M353	SE				
19	M353	NE				
20	M352	E				
21	N514	S				
22	M351	N				
23	M329	NE				
24	M329	S				
25	M329	E				
26	M329	S				
27	M329	SW				
28	G418	N				
29	G418	N				
30	G418	W				
31	G418	W				
32	G418	E				
33	G418	SE				
34	G418	N				
35	PIPES	W				
36	PIPE CONTROLS	S				

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP PHOTOGRAPHIC REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM120	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	N550 COMPLEX	N				
2	P722C	SE				
3	P781	N				
4	P745	E				
5	P718	N				
6	P703	E				
7	P703 SHOE LOCKER	N				
8	P703 TROLLEY	N				
9	R636 DOORS	S				
10	STEEL BLAST WALL	N				
11	G401	SW				
12	G401	W				
13	G451	NW				
14	G451	W				
15	SS552	SE				
16	SS552	S				
17	SS553	S				
18	SS553	E				
19	SS553	E				
20	SS553	SE				
21	SS554	S				
22	SS554	NW				
23	SS554	W				
24	SS555	S				
25	SS558	S				
26	SS558	NW				
27	SS556	N				
28	BETWEEN 558 & 556	N				
29	BETWEEN 558 & 556	NW				
30	SS108	S				
31	RANGE SIGN	SW				
32	R689	S				
33						
34						
35						
36						

ESSEX COUNTY COUNCIL
FIELD ARCHAEOLOGY GROUP REGISTER

SITE CODE	FILM NO & TYPE	ASA	120/35mm
wass96	WM121	125	35mm

SHOT NO	SUBJECT	DIRECTION OF VIEW	SCALE	DATE	INITIALS	RETURNED
1	SS557	SW				
2	SS557	W				
3	P722C	E				
4	SS504	SW				
5	SS553	SW				
6	SS553	SE				
7	SS553	E				
8	SS562	NW				
9	SS562	SW				
10	M COMPLEX	W				
11	SS209 SS211 SS213	W				
12	SS209 SS211 SS213	NW				
13	M348 MACHINE					
14	M348 SHOE LOCKER					
15	M348 HIDE FLOOR					
16	M COMPLEX	NE				
17	CONTRABAND SIGN	S				
18	GRINDING STONES	N				
19	GRINDING STONES	W				
20	HORSES					
21	N535 SHORING	NW				
22	N536 ALARM TRIANGLE	W				
23	N535 ELECTRIC BOX					
24	N535/6 SHORING	W				
25	N539	N				
26	N540	W				
27	N550	SE				
28	N531	W				
29	N531 WINCH	N				
30	G440	N				
31	N531`	E				
32						
33						
34						
35						
36						

13.3. APPENDIX 3

ARTEFACTS

POTENTIAL ARTEFACTS

for Waltham Abbey Royal Gunpowder Museum (WARGM)

Many items have been identified on South Site that would be suitable in a collection of a new national museum on the history of explosives and propellants manufacture. The accompanying list identifies all the items noticed by the building recording teams and does not represent a body of items being offered by RO to the proposed North Site museum.

Although it has not been possible to spend any length of time considering the relative importance of any artefact on a local, national or international level, it would be possible at this stage to identify some of the more outstanding items on South Site.

Buildings

Some of the older buildings on site may be considered as artefacts in themselves.
The circular timber structures in plan [N544, 486] that survive within their earthwork traverses and were part of the second NG facility on Quinton Hill, built after the 1896 explosion, are exceptional survivors as most timber structures of this date have been decontaminated by fire. The proposed North Site museum site contains suitable earthworks for such a timber structure to be housed within, should this option be chosen.

The **Box Store** [M349] is also an interesting timber structure that is little changed since 1892 and has excellent survival of the steam heating infrastructure (see Steam Supply).

Artefacts

In [P712] the Dilly Carts for truck drying solventless cordite paste exist complete with the hoods for blowing hot air through the racks of dough.

In [P716] a 10½ inch horizontal hydraulic press for extruding large diameter solventless cordite sticks is retained.

In [P718 and P706] vertical solvent cordite presses remain in situ. [P718] example has better survival of the fume extractor hoods and other service pipes.

In [P708] a collection of items recovered for Powfoot and other RO factories, as well as some from South Site, are located in a holding area.

Many other buildings have particularly explosive related items within them, or as part of their door or window furniture and some consideration should be given to this before demolition. For instance, the Refuges, covered under Passive Air Defence, contain fixtures and fittings including twin elsans and benches.

It is stressed that all items should undergo a suitable decontamination procedure prior to being transported or displayed to the public. RO's Environmental Services Group is particularly well placed to advise on this, having been closely involved on North Site in a similar exercise. It may be that severe contamination will restrict the release of potential museum artefacts. In the case of composite timber/copper items, recovery of the copper fittings may be the only available option, the timber being too absorbent to be safely exhibited or transported.

Documentation

Held in the **Fire Station** [P745], a vast archive of paper based records is being looked after, heating being provided during the winter months. Parts of the archive relevant to this report are listed in Appendix 1. Despite the care it is afforded, damage from fire or theft is still a possibility and RO have indicated that they would be consider relocation to the WARGM site or to another suitable repository.

Artefacts

Area:	NGR:	Artefacts:
495	TQ37899947	Fan machinery (corroded)
G432A	TQ38189976	See G432B
G432B	TQ38219977	Cast iron scales by E.and G.Corderoy
G442	TQ38139975	Marble drinking fountain and cattle trough with fittings, immediately to N, engraved 'Metropolitan Association Drinking Fountain and Cattle Trough'
M316	TQ37739977	1 telephone.
M348	TQ38089950	Boiler machinery in the Eastern annexe. Shoe lockers.
M349	TQ38549947	Many wooden storage/transit boxes and leather trunks. Benches, tables, lab. equipment. Old circular blade. Gas cylinder within a wooden frame.
N531	TQ38399974	Thermometer on E wall. Winch and lift. Control box. Telephone.
N532	TQ38359970	Blackboard on inside of door.
N538	TQ38489968	Motor mounted on traverse to northeast
N539	TQ38499968	Generator mounted on platform to northeast.
N552	TQ38569946	Machinery. Fire Proceedure sign on wall.
N557	TQ38379958	Wood bases for tubs. Lids? of washing tubs?
N569	TQ38389948	This building has an outside weighing station.
N570.	TQ38389946	2x Temperature recording equipment. " Cracking and Stability Trials " Literature by the East door.

Artefacts

Area:	NGR:	Artefacts:
N572	TQ38399942	Large Flow Chart in Bay 3.
Area:	**NGR:**	**Artefacts:**
N588	TQ38339957	Boilers. Air motors/filters. Doulton ceramic acid tank. 'Demi Rollit Plant' typeCT (acid washer?) WA21749
Area:	**NGR:**	**Artefacts:**
p704	TQ38409934	'Special rules' note on outside entrance wall.
Area:	**NGR:**	**Artefacts:**
p705	TQ38359934	2 blackboards, various 'safety' and 'fire' signs.
Area:	**NGR:**	**Artefacts:**
p706	TQ38329933	Tangyes Vertical press (1939), Cordage blast curtain, Red toe board, Telephone.
Area:	**NGR:**	**Artefacts:**
P708	TQ38279939	Minatol Soap Dispenser
Area:	**NGR:**	**Artefacts:**
P709	TQ38089929	Light Fittings, Contraband Box
Area:	**NGR:**	**Artefacts:**
p712	TQ38099925	5 red painted roofed wooden trucks, 'Marsden' scales.
Area:	**NGR:**	**Artefacts:**
p714	TQ38199920	Boot box, Signage in rooms denoting function, Blackboard
Area:	**NGR:**	**Artefacts:**
p715	TQ38279930	Cordage blast curtain.
Area:	**NGR:**	**Artefacts:**
p716	TQ38299922	Large horizontal press, 'Cambridge Recorders', steel blast door
Area:	**NGR:**	**Artefacts:**
P717	TQ38409928	Clocking in board (in traverse entrance), Use list, Fire exit plans, Instruction and Limits notices, Pressure Gauge, Blackboards, Switch for 'Bride' pump, Incorporation of Wet Paste Mixes sign.
Area:	**NGR:**	**Artefacts:**
P718	TQ38479928	Metal shoe lockers, Benches, Fire Certificate Book with detailed plan, Instruction and safety notices for the removed machinery throughout. Rm 1- use list, Tangye Press (moved). Rm 2 - Melvin cutter blackboard notice, Rm 3 - Tangye Press (1939). S corridor - red toe boards, 'Leafields' control panel and analogue unit. Die Store - machine starters and monitors. Motor Room - motors (Brook Motors and Frazer Mono Radial), pumps and starters. Control Room - 'Cambridge' recorder, Eng. Elec. Induction motor, 'Finney' hydraulic pump, pump.
Area:	**NGR:**	**Artefacts:**
p720	TQ38529921	Telephone in corridor, Cordage blast curtain

Artefacts

Area:	NGR:	Artefacts:
P722a	TQ38079908	Emergency telephone cabinet, two emergency telephone signs
Area:	**NGR:**	**Artefacts:**
p723	TQ38349916	Red toe boards, not in situ
Area:	**NGR:**	**Artefacts:**
p725	TQ38449915	Firing Test Bed. Bench mounted lathe.
Area:	**NGR:**	**Artefacts:**
p726	TQ38429915	Hook arrangement for fire buckets on N.wall. 2 'Cyclone' fans. Starters and Motors. Fire Drill notice.
Area:	**NGR:**	**Artefacts:**
p727	TQ38409916	Hoists, temperature gauges, pressure gauges, centrifugal pump, calorifier, motors and switches
Area:	**NGR:**	**Artefacts:**
P729	TQ38229914	'Pull to operate drencher' sign and red handle, hoist, cordage blast matting.
Area:	**NGR:**	**Artefacts:**
P730	TQ38299932	Notices re. RAPIER PRODUCTION and BRAMLING PRODUCTION
Area:	**NGR:**	**Artefacts:**
p731	TQ38309932	Red shelving unit
Area:	**NGR:**	**Artefacts:**
P733A	TQ38319929	Notices re. N572
Area:	**NGR:**	**Artefacts:**
p739	TQ38339925	Ammunition boxes
Area:	**NGR:**	**Artefacts:**
p740	TQ38239923	Cordage blast curtain
Area:	**NGR:**	**Artefacts:**
p741	TQ38119916	Weighing Scales - Marsden (WA 21747), Boot Bench, Ericson Telephone in metal case, Modern metal lockers, Rule list, Use list.
Area:	**NGR:**	**Artefacts:**
p745	TQ38439924	Three large metal upright chemical storage tanks, one for ACETONE, two for ALCOHOL. Wooden CHEMICAL signs. Pressure Gauge.
Area:	**NGR:**	**Artefacts:**
P747	TQ38589932	Official Secret Act Sign and two others. Large notice board.
Area:	**NGR:**	**Artefacts:**

Artefacts

Area:	NGR:	Artefacts:
R653	TQ37888991	Sign "Corrosion Risk"
Area:	**NGR:**	**Artefacts:**
R656	TQ37779909	One Allen and West power junction box. four telephones. one Sandamax 100 amp, 500 volt junction box. One British Berkefeld filter.
Area:	**NGR:**	**Artefacts:**
R662	TQ38078997	Forty safety/first aid posters.
Area:	**NGR:**	**Artefacts:**
R663	TQ37978996	Filing cabinet. Bay 2. Vapec steam humidifier (modern). Control/fuse box WA37592. Device for measuring humidity/temperature: Foster Cambridge Ltd Pc 15803 (serial number). Fire alarm control panels. Radio frequency interference filters (Belling-Lee). Battery charger.
Area:	**NGR:**	**Artefacts:**
R664	TQ37978996	Fixed lift up to platform.
Area:	**NGR:**	**Artefacts:**
R665	TQ37878996	Wooden fume cabinet. Lab benches/sink. Bakerlite Teddington thermostat. British Therm Co, Bunbury Middlesex.
Area:	**NGR:**	**Artefacts:**
R666	TQ37788995	Use list R666 bay 4. Lab benches etc. Fume hood/shaft. Red toe boards (not in situ). Control panel for compressor in bay 4. Operating instructions for sieve shaker. Use sheet bay 3. Fume extractors(3), Wall mounted heating ? elements(3). Arso Thermostat. Entrance- cabinet for breathing apparatus. Fire certificate folder including local site map and building. Fire alarm log book.
Area:	**NGR:**	**Artefacts:**
R667	TQ33708994	Steam piping with attached pressure gauge. Thermostat attached to steam heating: Sarco Thermostats Ltd, Cheltenham; serial No 27354.
Area:	**NGR:**	**Artefacts:**
R669	TQ37778980	First aid poster. Lab benches/drawers. Pressure gauge.
Area:	**NGR:**	**Artefacts:**
R671	TQ37758987	Various motors.
Area:	**NGR:**	**Artefacts:**
r672	TQ37858988	Waste Rags Dustbin and Broom. Wooden and metal trolleys.
Area:	**NGR:**	**Artefacts:**
R675	TQ37908993	Danger signs.
Area:	**NGR:**	**Artefacts:**
R677	TQ37908991	Two Vertical pumps. Associated junction boxes and controls. One tin of Wallwin Special Grease.
Area:	**NGR:**	**Artefacts:**
R678	TQ37898997	Metal cabinet (no makers name visible). Terrorist activity notice.

Artefacts

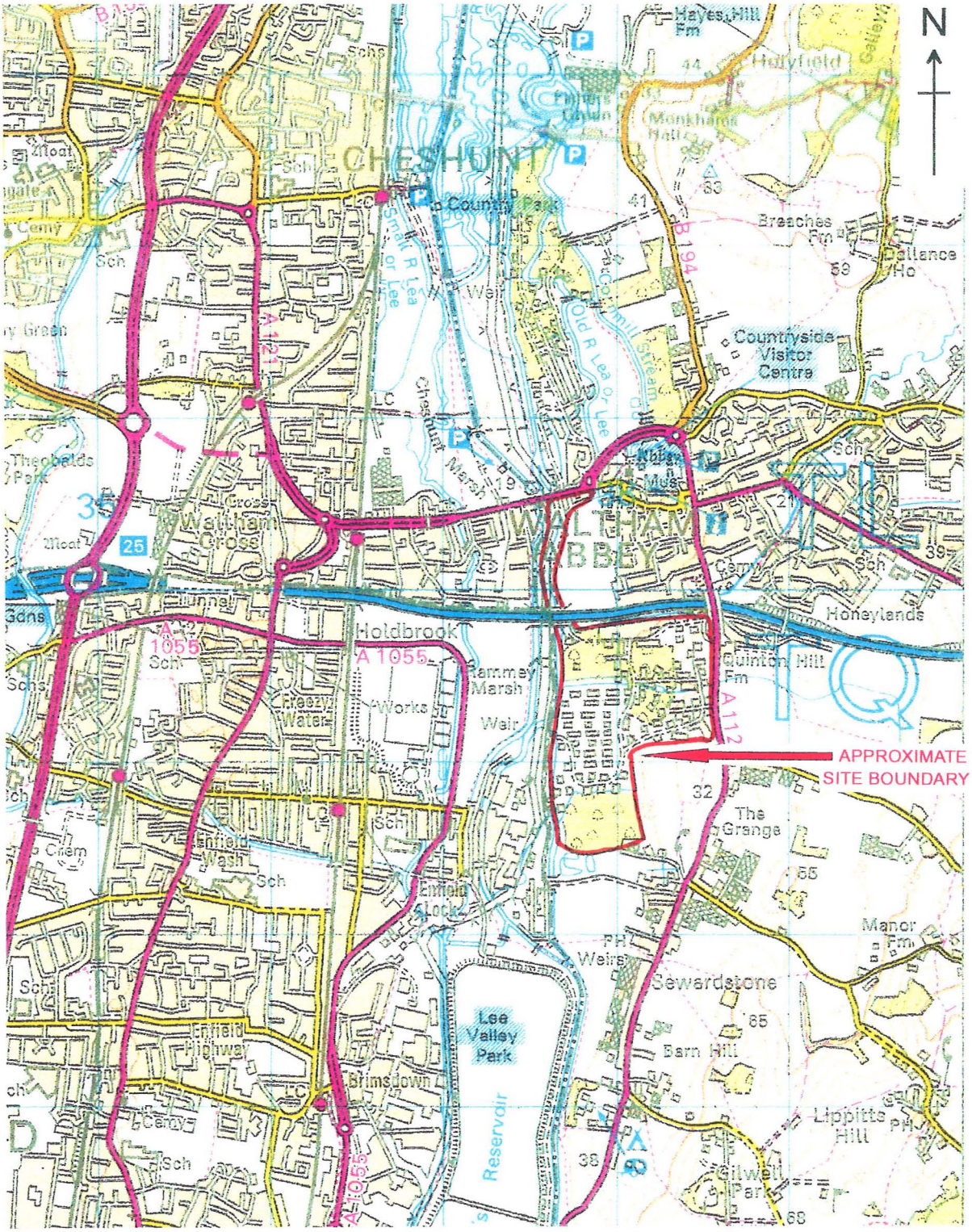
Area:	NGR:	Artefacts:
R679	TQ37898997	As R678
Area:	**NGR:**	**Artefacts:**
R680	TQ37718995	Sign showing limits of explosives per locker.
Area:	**NGR:**	**Artefacts:**
R684	TQ37818967	Control buttons. Site plan. Notice regarding what to do in case of terrorist activity. Bell.
Area:	**NGR:**	**Artefacts:**
R688	TQ37749904	Explosive Limit Sign. (Interior) .
Area:	**NGR:**	**Artefacts:**
r691	TQ37728995	Paperwork showing Use, Safety Limits and Classification (dated 16/5/83).
Area:	**NGR:**	**Artefacts:**
R693	TQ38088989	Eight metal corrosive bins.
Area:	**NGR:**	**Artefacts:**
ss100	TQ37708974	Wooden telephone cabinet with phone.
Area:	**NGR:**	**Artefacts:**
ss101	TQ37708974	Cast iron barrier manufactured by 'Tulley Engineering Co. Ltd., Notts.' serial number 15530
Area:	**NGR:**	**Artefacts:**
SS113	TQ38079918	'Austral Auto Flush Cabinet' x 2
Area:	**NGR:**	**Artefacts:**
ss114	TQ38089916	'Whites Burner' Blast Furnace, Lead ingot moulds
Area:	**NGR:**	**Artefacts:**
ss117	TQ37939903	Bakerlite phone.
Area:	**NGR:**	**Artefacts:**
ss123	TQ37879905	Between R654 and R651.
Area:	**NGR:**	**Artefacts:**
SS229	TQ38469973	Light fitting.
Area:	**NGR:**	**Artefacts:**
SS230	TQ38329952	Entire building
Area:	**NGR:**	**Artefacts:**
SS501		'A', 'B', 'C' and 'D' type hangers. Pressure gauges. Connecting valves.

APPENDIX 4

PLANS:

This appendix contains the location plan of the site only. The other plans, including the topographical survey, are bound in a separate volume and held in plastic wallets. A table showing of the contents of appendix 4 follows:

Period	Date	Description Heading
I	pre 1887	Ordnance Survey 1st Edition copy
II	1887 - 1890	New NC Factory
III	1890s	New NG Factory
IV	1900 - 1913	Cordite MD factory & Drying Stoves
V	1914 - 1918	1st WW further developments
VI	1919 - 1938	RDX
VII	1939 - 1945	None provided
VIII	1945 - 1991	Topographical Survey at 1:1250
VIII A	1945 - 1991	Project 1
VIII B	1945 - 1991	Project 2
VIII C	1945 - 1991	Project 3
VIII D	1945 - 1991	Ballistic Assessment



BASED UPON THE ORDNANCE SURVEY MAP WITH THE SANCTION OF HM STATIONERY OFFICE. CROWN COPYRIGHT RESERVED.
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FIGURE TITLE:

SITE LOCATION PLAN

PROJECT:

WALTHAM ABBEY SOUTH SITE

REPORT NUMBER:

ESG 2391/97

BRITISH AEROSPACE
ROYAL ORDNANCE
ENVIRONMENTAL SERVICES GROUP

INT3-97/2391/97

APPENDIX 5

PROFESSIONAL PAPERS:

The collection of professional papers, which cover all buildings and structures on the site, are bound in separate volumes which are defined by number prefix.