WASC 1999

RARDE Open
Day Brochure
20-6-1986

Royal Armament Research and Development Establishment

Waltham Abbey, Essex.

Open Day to Industry Friday June 20th, 1986.

RARDE, Waltham Abbey, will be displaying a number of lines of research which have applications beyond the defence field. These include:-

ADHESIVES
- High temperature adhesives
- Durability of adhesion
- Surface pre-treatment for adhesives

KEVLAR REINFORCED COMPOSITES
- Mechanical behaviour
- Life prediction under different environments

TESTING OF MATERIALS UNDER A WIDE RANGE OF TROPICAL ENVIRONMENTS

USE OF INTUMESCENT PAINTS

NEW NITRATION PROCESSES

COMMERCIAL ELECTROLYTIC PROCESS FOR PRODUCTION OF N_2O_5

NOVEL THERMO-PLASTIC ELASTOMERS

Those interested should complete the following form and return to Management Services, RARDE Powdermill Lane, Waltham Abbey Essex EN9 1AX Tel: Lea Valley 713030 ext 256.

Owing to severe restriction in numbers, entrance can be by formal invitation only.

I would like to attend RARDE, Waltham Abbey Open Day

I shall/shall not require transport from Waltham Cross (BR) Station

I would like further detailed information

Name..

Affiliation..

Position..

Address...

Ministry of Defence
Royal Armament Research and Development Establishment

Waltham Abbey
Essex

Open Day to Industry
Friday June 20th, 1986.

Propellants Combustion and Chemistry Group

To Rick

Welcome to our Open Day which is sponsored by the Ministry of Defence and the Department of Trade and Industry to promote the transfer of technology in MoD Establishments in general and in this instance RARDE Waltham Abbey in particular.

The programme for your visit during which we hope to be able to show you some of the research facilities and topics here at Waltham Abbey is as follows:

9.20-10.00	Visitors will be welcomed at our Library, North Site for Coffee.
10.00	Welcoming address by Dr A J Owen, Head of RARDE Waltham Abbey.
10.20	Introduction on the purpose behind the OpenDay by Dr Lewison and Dr Stewart, Deptment of Trade & Industry.
10.35	Tropical Testing, the work of JTTRE, Dr A Davis.
11.15	Departure to the South Site by bus.
11.25	Divide into three parties for the visit to the Synthetic Chemistry and Pilot Plant Sections (group A), Composite Materials (group B), and Adhesives (group C).
12.30	Lunch, South Site Canteen.
1.15	Group A to Adhesives, group B to Synthetic Chemistry & Pilot Plant, group C to Composites.
2.20	Group A to Composites, group B to Adhesives, group C to SC & PP.
3.20	Return to the Library, Concluding comments.
3.45	Tea. Transport to Waltham Cross Station.

The structure of the Research Establishment is still under examination following the split of PERME into RARDE and the Royal Ordnance plc (on the South Site). The MoD Sections will remain at Waltham Abbey for the time being until plans have been finalised and implemented for the move to Fort Halstead, Kent. The Sections currently active at Waltham Abbey which you will see today are as follows:

Hd/RARDE (Waltham Abbey) and
Hd/Propellants Combustion Chemistry Group

Dr A J Owen

PC1 Division
Dr T Lewis

Composites, Mr N J Parratt

Synthetic Chemistry, Dr P Golding

Pilot Plant, Mr G Bagg

PC3 Division
Dr J Jenkins

Tropical Testing, Dr A Davis

Adhesives, Dr D Tod

Production of N_2O_5 for Nitration Reactions

Contact: Mr G Bagg, Pilot Plant Section.

Introduction

Nitrations employing N_2O_5 chemistry have been known for some years but have remained laboratory curiosities because of the uneconomic production techniques previously available for this reagent. RARDE Waltham Abbey has developed commercially viable processes for N_2O_5 production. These can be licensed through Defence Technology Enterprise and the Patents Branch by sections of industry wishing to explore the tremendous potential of this previously unavailable nitrating agent.

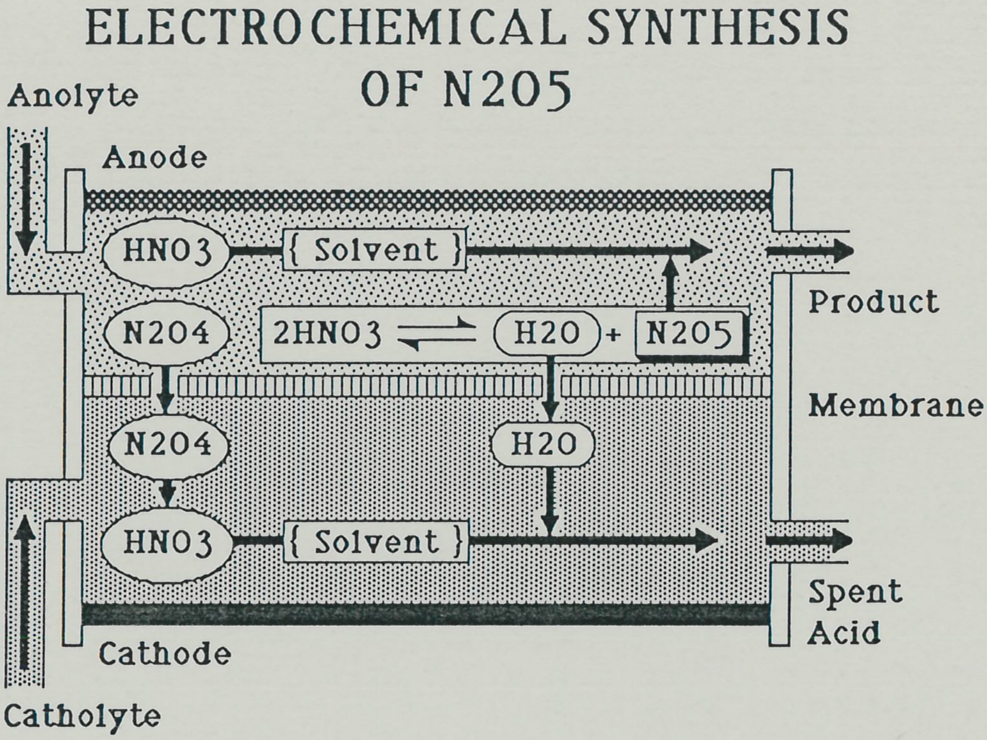
The Products

A unique electrochemical cell, capable of synthesising N_2O_5 from nitric acid in kg quantities, has been constructed by Jordan Engineering Ltd., Bristol, for our development use. N_2O_5 generated by this equipment can be used to perform nitration reactions, employing nitric acid as solvent. This system has general applicability as a replacement for conventional techniques, employing nitric acid/sulphuric acid or nitric acid/oleum mixtures, where increased product purity/yield, reduced reaction time and simplified process design can offset additional reagent costs. The N_2O_5/nitric acid system may find particular application in the synthesis of nitroaromatic intermediates, which are used extensively throughout the chemical industry (eg. in synthesis of dyestuffs, pesticides, explosives etc.).

The Process

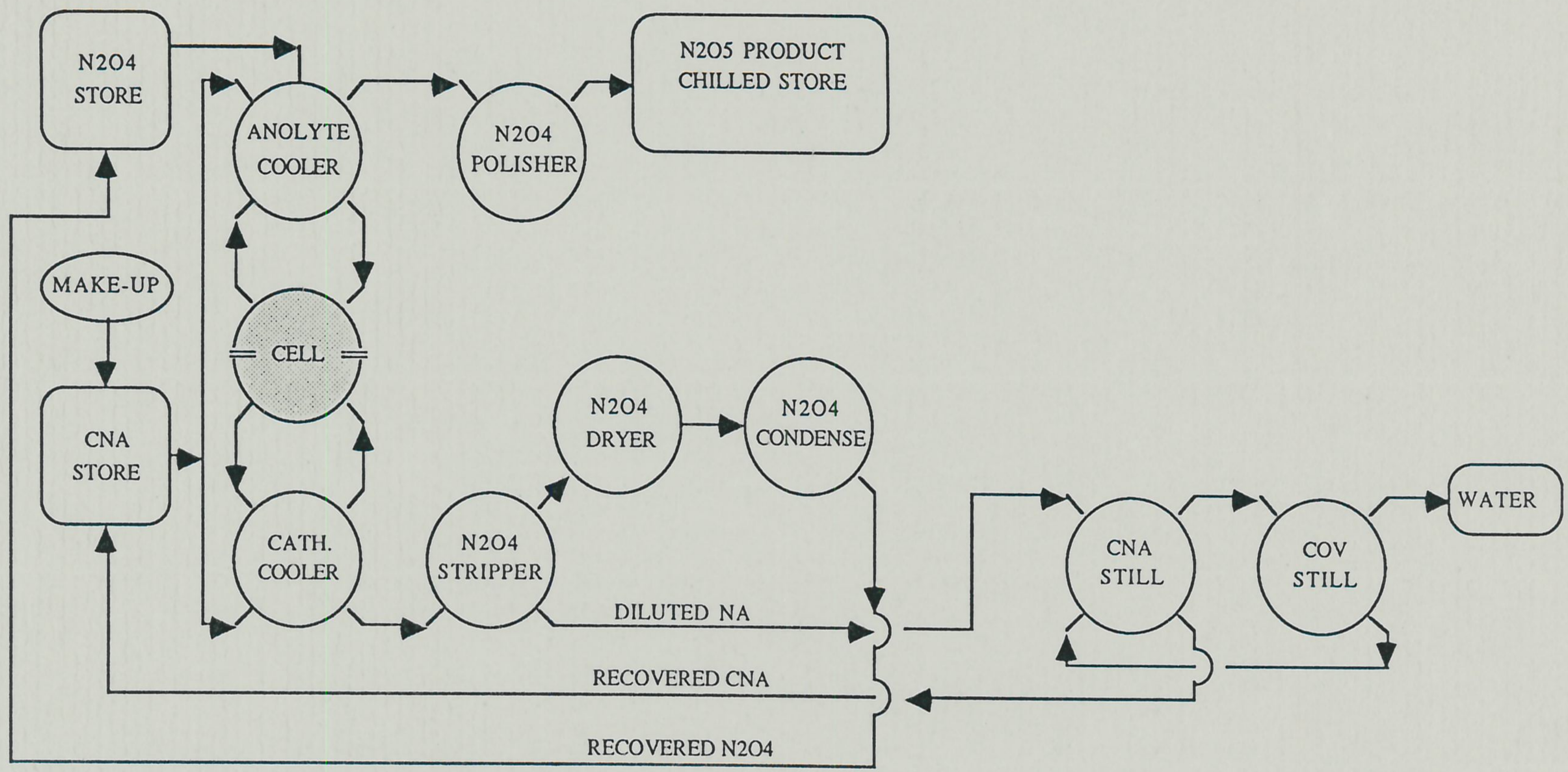
In principle, a continuous cell consists of two narrow chambers bounded by electrodes and separated by a semi-permeable membrane. Through these chambers flow two different mixtures of electrolytes whose constituents are changed by the passage of electricity. The combination of electrical current, electrode materials, membrane separator and electrolytes all help to control the efficiency of the reversible reaction shown in the centre of the cell. Nitric acid is split into water and N_2O_5 with the assistance of the N_2O_4 using excess nitric acid as the solvent. The water so formed is separated by the membrane from the anolyte thus preventing recombination back to nitric acid. Any water present in the anolyte stream will be converted to nitric acid so that the cell is also a very good system for producing true 100% nitric acid.

A simplified schematic of the net reactions is shown as follows:



This method for the synthesis of N_2O_5 has been known since the beginning of the century but was incapable of development due to the aggressive nature of the components and the limited technology of suitable containment materials available. RARDE Waltham Abbey has been responsible for the design and development of a custom cell and pilot plant which can produce the quantities necessary for nitration evaluation studies as well as forming the technology package for future commercial exploitation in this field.

A typical process schematic for the operation of the electrochemical cell and associated pilot plant is shown overleaf.



A TYPICAL PROCESS SCHEMATIC FOR THE PRODUCTION OF N2O5
SHOWING THE CELL & PERIPHERAL PLANT FOR ELECTROLYTE
CIRCULATION & COMP0NENT RECOVERY

Novel Thermoplastic Elastomers

Contact: Dr P Golding, Synthetic Chemistry Section.

Introduction

The concept of thermoplastic elastomers has been in existence for many years, but physical properties of such materials have been intrinsically limited by the block-copolymer technology used to produce them. RARDE Waltham Abbey has developed a new approach to the generation of these materials which involves attachment of ionic end groups to a homopolymer. This technique offers considerable potential for the production of thermoplastic elastomers with improved physical properties. The new class of compounds so generated is of interest for a variety of applications.

The Concept

The attachment of ionic end groups to an essentially non-polar chain generates a system (an ionomer) in which two thermodynamically incompatible species are chemically linked together. The consequence of this is the formation of a domain structure in which the ionic groups associate to form micelles. If both ends of a polymer chain are terminated with an ionic grouping, opportunity exists for pseudo cross-linking because opposite ends of the chain can be accommodated in different micelles. If an elastomeric polymer chain is employed the material will exhibit rubbery properties up to a certain temperature. Above this temperature, the ionic micelles break up and the material will begin to flow. The process is reversible and on lowering the temperature the micelles reform and the material becomes once again elastomeric.

The Products

Synthetic methods have been developed at Waltham Abbey by which polybutadienes, terminated with various ionic grouping, can be prepared. The groups employed include quaternary ammonium, boronate and sulphonate moieties. A range of such products have been produced with differing molecular weights and variation of the substituents associated with the ionic groupings. Some preliminary examinations of the physical properties of these materials have been undertaken. Polymers in which only one end of the chain has been terminated by an ionic group have also been prepared.

A specific advantage of this class of material as compared with conventional block copolymer technology, lies in the small size of the terminal ionic groupings and hence of the ionic domains in which they reside. These aggregates typically have molecular weights of a few hundred which is in sharp contrast to more conventional eg Styrene-Butadiene-Styrene (SBS) systems, where the polystyrene blocks (which fulfil a similar function to the ionic micelles) have molecular weights nearer 20,000. Because of this it is possible to reduce the polybutadiene chain length to about 3,000 whilst retaining elastomeric properties. It is this reduction in chain length (ie diminished distance between (pseudo) cross links) and the corresponding reduction in overall matrix size which offers potential for improved physical properties. In particular it optimises the rubber characteristics of the materials and tends to enhance their strength.

The unique properties of this novel class of ionically terminated polybutadienes give them potential for a number of different applications aside from use as a bulk rubber. These include adhesives - for bonding of physically incompatible materials (polymer to metal, polyamide to polyethylene etc) surface coatings (eg organic film over metal) and emulsifiers. Information on the various products and the techniques for their synthesis is available to interested parties.

Adhesives

Contact: Dr D Tod, Adhesives Section.

Adhesives are a very versatile way of joining materials. As in any joining process there are advantages and disadvantages. For adhesives these include;

Advantages: Fabrication of complex shapes, ability to join dissimilar materials, good stress distribution in the joint, cost saving on manufacture.

Disadvantages: Lack of durability, relatively low upper operating temperature, lack of NDT methods, brittleness.

RARDE Waltham Abbey is involved in many aspects of adhesion research, three of which will be considered. These are durability, brittleness and high temperature resistance.

Durability

An adhesive joint must not only have good short term strength but also must retain its strength with time. Moisture can affect the long term performance of adhesive joints. Adhesives may be plasticised by absorbing water so that the cohesive strength of the material is lowered. The interphase region between the adhesive and the substrate may also be attacked by the ingress of water. In aluminium the oxide is hydrated by the water and eventually the water can displace the adhesive from the joint. Methods are available which preclude this attack, which involve the etching of the aluminium to stabilise the oxide. For steels, joint durability is normally improved by the use of a primer such as a silane. Short term accelerated tests can quickly demonstrate that an untreated steel joint will fail in minutes, whereas a treated joint will be stable. It can be shown that these pretreatments form a chemical bond across the steel-adhesive interface.

Toughening of Adhesives

Most adhesives are polymeric in nature and the most commonly used structural adhesives such as epoxy resin are thermosets. These materials have a high crosslink density and this imparts a high degree of brittleness into the sytem. A way of counteracting this is to incorporate a rubbery phase into the matrix resin. This phase acts as an energy absorbing medium so that the degree of brittleness is reduced. Quite considerable improvements in toughness can be achieved by this means. An untoughened epoxy adhesive may have a fracture energy of about 150 J/m^2 whereas a correctly toughened system can have a fracture energy exceeding 13000 J/m^2.

High Temperature Systems

Epoxies in general cannot be used above about 170°C. To achieve the higher temperature resistance now demanded it is necessary to move to a new class of adhesives. Polyimide adhesives have good high temperature properties. Condensation polyimides cure with the evolution of water. To prevent bubbles being formed in the joint it is necessary to apply pressure to the joint while it cures, which is obviously inconvenient in many applications. However, a further form of polyimide cures by an addition mechanism, where no water is produced thereby requiring no pressure during cure. These materials are very brittle so it is necessary to toughen the material by the addition of rubber as described above. Such adhesives have been produced and the fracture energy raised from about 10 J/m^2 to about 400 J/m^2.

Kevlar Reinforced Materials

Contact: Mr N J Parratt, Composites Section.

RARDE Waltham Abbey has specialised in the behaviour and use of this high-strength aromatic fibre, both in the form of resin-matrix composites, and as overwindings for metallic pressure vessels. Compared with conventional engineering materials variability and lack of chemical and thermal durability can cause problems which demand careful study. Topics covered here include

* Variation of mechanical properties with fibre microstructure
* Low cost testing procedures for precise quality control
* Statistical prediction of service life under stress and in different environments - modelling of degradation mechanisms
* Long term dimensional stability of Kevlar components
* Laminate and component behaviour under biaxial load and impact
* Stress analysis of fibre overwound vessels

Intumescent Coatings for lightweight fire protection

Contact: Mr J Cook, Composites Section.

An intumescent coating consists of a mixture of chemicals that can be applied to the outside surface of a store to a thickness that can vary from 0.2 to 12 mm depending on the application.
Beyond a certain threshold temperature the coating decomposes, expanding in volume as it does so, to give a thick stable char layer that is thermally insulating. Protection of the store is given by a combination of:

a. The insulating properties of the char.

b. Heat absorbed in decomposing the virgin coating material.

c. "Transpiration" cooling of the char as the gaseous decomposition products diffuse outwards through it.

Due to their compactness and light weight intumescent coatings have an important role in protecting sensitive equipment during a fire.

RARDE's special interests have been:

* Development of robust, permanent coatings for steel containers.
* Analytical methods for assessing the fire protection afforded by a coating of given thickness and composition.
* Calculation of the heat flow within complex weapon systems, and comparing these predictions with measured behaviour in major fires.

Tropical Testing, the Work of JTTRE

Contact: Miss D Howse

A new polymer is generally put on the market with a comprehensive account of its physical and mechanical properties. However, there is seldom information available to say how long the material will last outdoors before it needs repair or replacement. Exposure trials are an important means of obtaining this information. Such trials in tropical and sub-tropical regions are particularly useful because almost invariably the high levels of temperature, humidity and solar radiation found in these regions are more aggressive to materials than the conditions of temperate zones.

As well as being of intrinsic interest, tropical and sub-tropical exposure trials may be considered as a way of obtaining advanced information on the resistance of a material to temperate conditions.

To meet the stringent requirements of military equipment, the Autralian Department of Defence and the Ministry of Defence in the UK have, since 1963, collaborated to run the Joint Tropical Trials and Research Establishment (JTTRE) in North Queensland. JTTRE is jointly under the technical direction of the Materials Research Laboratories in Melbourne and RARDE. Miss D Howse, at Waltham Abbey is the UK Liason Officer for JTTRE.

The exposure sites at JTTRE offer a range of environments from Hot/Wet to Hot/Dry including jungle and marine immersion. In addition to the ususal meteorological measurements of temperature, humidity and rainfall, other environmental factors such as ultraviolet radiation and surface temperature are monitored.

Materials which have been exposed include rubbers, plastics, composites, adhesives, paints and metals. They are exposed in the form of cast test pieces or components with no restriction on size; bridge units and helicopter rotor blades are currently being exposed.

For materials which are destined for critical structural applications, rigs have been developed in order to expose them under mechanical stress. Sponsors may carry out their own evaluation of specimens or they can take advantage of the expertise and facilities at JTTRE for chemical, physical and mechanical testing.

While the prime function of JTTRE is to carry out work on behalf of the UK and Australian Defence Establishments, a limited number of commercial trials have been carried out. Discussion on further commercial use of the unique facilities at JTTRE would be welcome.

The Royal Armament Research and Development Establishment Waltham Abbey

Its Historical Background

M McLaren, Management Services.

The present Establishment at Waltham Abbey occupies the site with the longest continuous association with explosives. Just after World War II the Research Establishment took over from the Royal Gunpowder Factory which had provided a manufacturing capability since 1787 and which, in its turn, was the successor to the earlier privately-owned Powder Mills. No history of this Establishment is therefore complete without reference to the history of gunpowder itself.

Gunpowder is an emotive word which conjures up a whole range of impressions, from dastardly plots to festive celebrations, but for five centuries it remained the undisputed explosive and propellant and, as such, it served to change world history. At a more parochial level it is responsible for RARDE, Waltham Abbey being where it is today.

It is now accepted from the writings of Taoist alchemists, as early as the 9th century, that the Chinese were the first to develop incendiary mixtures of saltpetre, sulphur and charcoal and later, in 1044, to give detailed compositions of these mixtures. The availability of saltpetre and an awareness of its properties were key factors in this development. Knowledge of gunpowder then spread westwards to Europe through the Arab countries where saltpetre was unknown before the early part of the 13th century but later became known as "Chinese Snow". In Europe, Roger Bacon, a Franciscan friar, is credited with the earliest experimental investigations of gunpowder but he was so apprehensive of the consequences of his discoveries that in his account, written in the mid 13th century, he concealed the details of the composition in an anagram which, surprisingly, was not deciphered until 1904! Despite this secrecy the composition and its propellant properties became more widely known and led to the development of the gun, the earliest known illustration of which appears in a manuscript dated 1326 by Walter de Milemete, chaplain to Edward III. Twenty years later, after further development, the gun was being used for the first time on the battlefield by the English at Crecy in 1346.

Although some gunpowder was being made at the Tower of London, most of that used in the next two hundred years was imported from Europe where Antwerp and Hamburg were the main trade centres. It was not until the second half of the 16th century that the gunpowder industry began to expand, possibly as a result of the Queen's Ministers advocating, in 1560, the construction of new Powder Mills to overcome the shortage of gunpowder at a time of deteriorating international relations.

It was at this time that the earliest link between Waltham Abbey and gunpowder was established, appearing in the form of a letter from an Italian to John Tamworth of Waltham Abbey concerning the supply of saltpetre and sulphur. The early years of the Waltham Abbey Mills are shrouded in uncertainty but a legend exists that the powder used in the "Gunpowder Plot" came from Waltham Abbey. It is known that, just before that fateful day in 1605, the main conspirators were frequent visitors to White Webbs, a house in the nearby hunting district of Enfield Chase. The powder could have been purchased without suspicion and then transported by water down the River Lea to the Thames.

The importance of the Mills appears to have flourished as by 1662 Thomas Fuller, the local minister, was writing in his "History of the Worthies of England" that more gunpowder was made by the mills in his parish "than in all England besides". Fuller recognized that the manufacture of gunpowder was a dangerous occupation stating that the Mills had blown up five times in seven years but without the loss of life. It was however only three years later, in October 1665, that the local Parish Registers recorded the burials of two workmen killed in a mill explosion, a tragedy which must have been viewed with some concern as it was most unusual for the cause of death to be given in the registers.

The gunpowder industry was in private ownership and the Waltham Mills were no exception. Little is known of the early owners but the names of Richard Stock and John Berisford both appear as "powdermakers" in a land transaction of 1648. Samuel Hudson was the powdermaker in 1669 at the time of the earliest known, but still extant, title deed to the site in which details are given of buildings used for the processes of "grindinge, boylinge, corninge and dryinge of powder". The Mills then passed into the possession of the Walton family in whose hands they remained for three generations. By 1735 the Mills were owned by John Walton and were described in that year by John Farmer in his History of Waltham Abbey as being "esteemed the largest and compleatest works in Great Britain", and although no details of manufacture are given it is known that the powder mills were worked by horses but that water power was used for the "corning" and "glazing" engines. By 1770 the use of water power had spread to the powder mills which were then supplying "near one hundred barrels weekly for Government Service, each barrel containing one hundred weight".

In the 18th century the Government had realised the importance of controlling much of the gunpowder production and had, in 1759, purchased the mills at Faversham in Kent. However, following statements that the private merchants could make better powder than the Government and that they could make it more cheaply the Prime Minister, Pitt, was about to recommend the sale of the Faversham Mills in 1783, back to private enterprise. Representations were made, through the Master General of Ordnance by Major William Congreve, who was Deputy Comptroller of the

Royal Laboratory at Woolwich, to show that Government manufacture did, in fact, yield a profit, and that, if this profit were properly expended in improving the mills, it would be possible to make a powder which was more powerful and more durable than had even been made previously. Fortunately and justifiably - as shown later - he received a sympathetic hearing and not only were the Faversham Mills reprieved but negotiations were opened with yet another John Walton for the purchase of the Mills at Waltham Abbey. Walton's Mills were purchased by the Government in October 1787 for £10,000 and placed under the control of Major Congreve who expended a further £35,000 on improvement and enlargements as the Mills were in a state of neglect. By 1811 Congreve was able to justify his actions by publishing a statement of savings arising from the manufacture of gunpowder at the Royal Mills. Between 1789 and 1810, 407,408 barrels of powder, each of 100 lb were produced at Faversham and Waltham Abbey. The savings to the Government, being the difference between the merchants price and actual cost, amounted to £288,357 6s 0d. Taking the Waltham Abbey Mills alone, even after deducting £45,000 spent on the mills, a saving of over £50,000 was made. Much was also done at this time to improve the quality of the powder produced and Congreve demonstrated the improvements by trials on Marlborough Downs where 10-inch shells were fired by 9 lb lots of powder from different makers including six private merchants. That from the Royal Gunpowder Factory at Waltham had the greatest range of 4,430 yards exceeding its closest rival by 160 yards and most of the others by over 500 yards.

During the Napoleonic Wars the annual gunpowder production mounted. By 1809 20,000 barrels were produced, by 1811 21,000 and by 1813 it had risen to 22,000. After Wellington's victory in 1814 every effort was made to decrease output and only 10,000 barrles were produced. On Napoleon's escape from Elba in 1815 powder production was maintained but, after Waterloo, output was reduced drastically to 3,000 barrels in 1816 and to 1,000 barrels and less in 1819 and the following years. Employment in the factory had been 250 in 1813 but by 1822 the figure was down to 34! Waltham Abbey survived this contraction but the other Government factories at Faversham and Ballincollig in Ireland were sold back into private ownership.

Details of the processes for the making of gunpowder were given in a pamphlet by Major Fraser Baddeley entitled "The Manufacture of Gunpowder, as carried out at the Government Factory, Waltham Abbey" which was published in 1857. It is significant that this pamphlet, and by implication the work by the Waltham Mills, could have influenced world history. At the start of the American Civil War only three powder mills are known to have been in existance in the Southern States. Major George Washington Rains was given the task of supplying the Confederate Army with gunpowder and it is recorded by him that he had the "great good luck" to come by Baddeley's Pamphlet. Both Rains himself and the United States Ordnance Manual of 1862 express the opinion that "nobody makes better powder than the British". The one drawback of Baddeley's pamphlet is that, whilst it gives precise details of all the processes, it contains no drawings of machinery or equipment. Major Rains, however, managed to obtain the services of a James Wright, the grandson the the first Storekeeper of the Waltham Mills, who had emigrated to Tennessee. Rains wrote: "But one man - Wright - could be found in the Southern States who had seen the making of gunpowder by an incorporating mill; he had been a workman in the Waltham Abbey Mill in England.......... I was much indebted to his knowledge and experience". But the Royal Gunpowder Factory appeared to have been backing both sides for it is known that Antoine Biderman and his nephew Lammot du Pont, both of the large Northern powder company of Du Pont, paid separate visits to Waltham Abbey before the Civil War.

Mention has been made of the accidental explosions referred to by Fuller and the first fatal accident. Although other explosions did occur in the era of private ownership very little is known about them, but from the time the Government took over the Mills the records of explosions are virtually complete. There was a change of attitude from one of inevitability of explosions to one of understanding why they took place. In the early years of government ownership regulations were made tighter and precautions were introduced whenever they were seen to be necessary and advice was sought from the leading authorities in the country. Explosions in the incorporating mill were frequent but not usually serious because the "green" charges had weaker explosive power and did not damage the machinery. It was in the later stages of manufacture that the possibility of a serious explosion was greatest. The first of these occurred in 1801 when a corning house blew up killing nine men and four horses. After this incident an approach was made to the Royal Society to suggest the best floor coverings and a visit was made to the mills by a party which included the President, Sir Joseph Banks, Count Rumford and Henry Cavendish. Their report stated that there was no hazard from "electrical excitations in the practice of rolling barrels on floors covered in hide nor from the use of silk dusting screens", but recommended the use of painted floor cloth to cover the whole floor. In 1893 after an explosion in a building in which granulated powder was being pressed had caused the loss of nine lives, there was serious public concern. The Press was critical and questions were asked in the House of Commons. The report of the Committee of Enquiry, which included Lord Sandhurst and Sir Frederick Abel, can be said to be the basis of modern safety practice in explosives manufacture, for not only did it indicate the probable cause of the incident, but it discussed at some length the deficiencies of procedures and regulations.
For centuries the entire production of the Factory had been gunpowder but by the middle of the 19th century there was growing interest in two new explosives, guncotton and nitroglycerine.

Guncotton had been made by Schonbein of Basle in 1846 by the action of nitrating acids on cotton, and a plant for its production was set up at Faversham, now once again in private hands. Unfortunately, a serious explosion destroyed the plant and following explosions elsewhere in Europe little interest was shown in guncotton except in Austria where the processes were improved. So much so that the Austrian Government offered details to the British Government and Frederick Abel, the War Office Chemist, was instructed to examine these improvements. Abel commenced experimental production at Waltham Abbey in 1863 according to the Austrian recipe. Later, he developed his own process for pulped guncotton which could be compressed into any desired shape suitable for use in mines and torpedoes or for blasting purposes. In 1872, he was authorised to set up a plant to produce 250 tons a year. Eventually this plant proved to be inadequate to meet the ever increasing demand and a new site on the southern side of Waltham Abbey was acquired.

In 1872 Colonel Younghusband, the Superintendent of the Royal Gunpowder Factory wrote: "A great future may fairly be anticipated for Guncotton. As regards safety in manufacture, storage, transport and use, it is unrivalled by any other explosive, while in power it has not been surpassed by any substance with which it has been compared".

Nitroglycerine, a liquid explosive, first made by Sobrero in 1847 by the action of nitrating acids on glycerine, was the subject of much experimentation by Nobel but after several accidental explosions its importation and manufacture were prohibited by many Governments. Nobel's experiments were directed towards making nitroglycerine more easily handled than it was in its liquid state and one product he prepared was a mixture of nitroglycerine, guncotton and camphor. At this point Abel took up the action for the Government and made a mixture of nitroglycerine, guncotton and mineral jelly which gave promising results. This mixture which could be made into a charge of cords or rods received the name cordite. In 1891 a nitroglycerine plant was erected at the Factory together with the necessary buildings for the making of cordite. A second plant was built shortly afterwards and during the Boer War the production of nitroglyerine was about 18 tons a week.

Modifications to the original processes were introduced for all three products; guncotton, nitroglycerine and cordite, and for cordite there were variations in the ingredients. Production of cordite was about 40 tons per week in 1907 but at the height of the 1914-18 war it was about 64 tons per week.

The time between the wars were lean years for the Factory but even with a depleted staff research continued and improvements made including the introduction of nitroguanidine, or picrite, into the cordite to lessen flash and smoke. Also a solventless process, which was safer and eliminated a drying stage, was introduced.

Although Colonel Younghusband in 1872 had spoken of guncotton in such glowing terms this did not prevent the search for other explosives. Abel comes back on to the scene again for it was he who suggested " picric powder", a mixture of saltpetre and ammonium picrate, and arranged for its manufacture at Waltham Abbey.

TNT, probably the most widely known high explosive, is made by the action of nitrating acids on toluene, but, although it came into use in the British Services in the First World War, it was not until 1933 that it was made at the Royal Gunpowder Factory.

At this time the Factory was a production unit, whilst at the Research Department at Woolwich, work was being carried out to improve old processes and to introduce new explosives. One line of research led to the Research Department Explosive, RDX, and plant for its production was set up at Waltham Abbey in 1938. RDX or cyclotrimethylene trinitramine, has been called the high explosive of World War II. It is therefore significant that for the first years of the war the Waltham plant was this country's sole source of production.

As the war continued so other Ordnance Factories took over the production of the various explosives and the contribution of the Royal Gunpowder Factory decreased. In the winter of 1940-41 an enemy land mine put out of action the last of the gunpowder mills and the production of gunpowder, which had given the factory its name, was not resumed. Towards the end of 1943 most of the plant was being run down and on 28th July 1945 the Royal Gunpowder Factory was formally closed after nearly 160 years.

This closure was foreseen and as a result of a survey in 1944 the site was reopened on 30th July 1945 as an Experimental Station of the Armament Research Department at Woolwich. In 1946 there came into being the Chemical Research and Development Department with a nucleus of scientific staff drawn from the explosives and propellant branches of the Armament Research Department. Thus the link with Woolwich which had begun with Sir William Congreve, was continued. The name of the department changed in 1948 to the Explosives Research and Development Establishment. Conversion of the factory site to the new Establishment was in immense task but gradually rehabilitation proceeded. The first programme of the new Establishment was divided into eleven items each of which was a distinct branch of research having a direct relationship to Service problems: Liquid Propellant Systems, Plastic Rocket Propellants, Colloidal Rocket Propellants, High Explosives and Intermediates, Initiators, Chemical Engineering Small Arms and Mortar Propellants, Materials, Unorthodox Propellant Systems, and Ancillary Chemical Services.

But change has never been far from the Establishment's activities and the passage of time has seen it in six different Ministries with the number of branches increasing the 1960s (9 in 1963) and decreasing in the 1970s reflecting the changes in those activities. Following the formation of a joint Establishment with the Rocket Propulsion Establishment at Westcott in 1973 a reorganisation in 1977 led to the creation of the Propellants, Explosives and Rocket Motor Establishment.

Work continued on the revised PERME programme until 1984 when, as part of a scheme to privatise the Royal Ordnance Factories, the site at Waltham Abbey was divided between the Royal Armament Research and Development Establishment and what is now the Royal Ordnance plc.

The current activites of RARDE Waltham Abbey are related to responsibilities for research and development to maintain a capability associated with propellantry and rocketry.

Official Address:-

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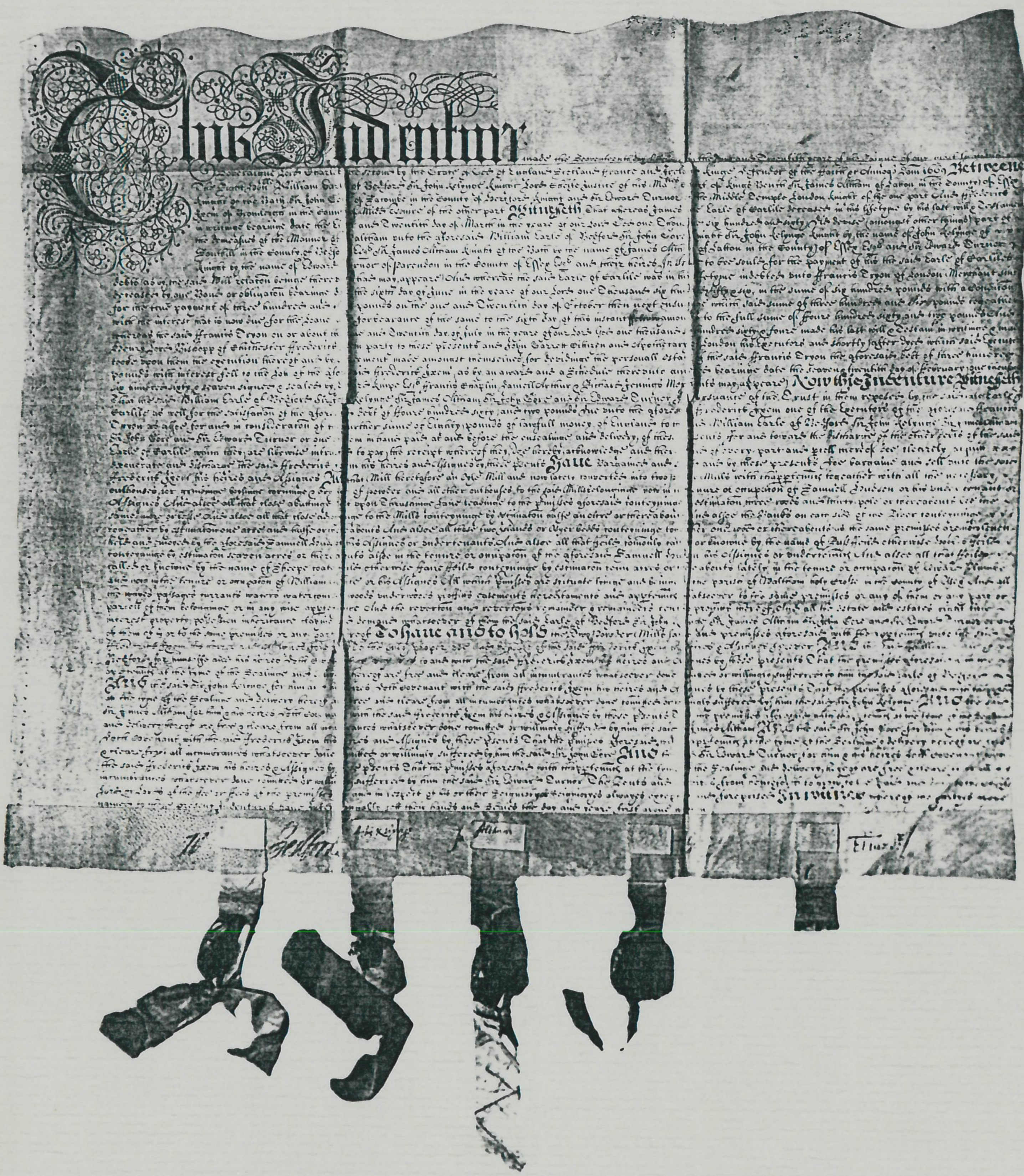
Telephone: Lea Valley (0992) 713030
Telex: 25310
Facsimile: extension 298

WALTHAM ABBEY POWDER MILLS

The Earliest Known Title Deed to the Site - 1669



The deed names Samuel Hudson as the powdermaker and includes the site description as "....two powder mills ....with all the necessary outhouses for grindinge boylinge corninge and dryinge of powder".

Lt. General Sir William Congreve - Controller of the Powder Mills
after purchase by the Government in 1787.
(above)

An Early Engraving of the Establishment in the Days of the
Powdermills 1735.
(overleaf)

1. A Horse Mill	8. The Carpenters and Mill-wrighs work house	15. The Charging house
2. The Corning and Glazing Engine	9. The Clerks Counting house and the Watch house	16. The old Composition house
3, 4, 5. Three Horse Mills	10. The Loading house	17. The Store house
6. The Stables	11, 12. Two Stamping Mills	18. The Dusting house
7. The Coal Mill and Composition House	13, 14. Two Dumb Mills	19. The Little Stove
		20. Three Sun Stoves, or drying Leads
		21. The great Store

To John Walton Esq.r Proprietor of these Mills this Plate is humbly dedicated by his Obedient humble Servant J. Farmer

R. H..d delin 1735. Jn.o Mynae Sculp.

Electronically composed and printed on the
Macintosh, Laserwriter System.
PP/PC1 Section.