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Explosives in the Service of Man

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Royal Commission on the Ancient and Historical Monuments of Scotland

ICI

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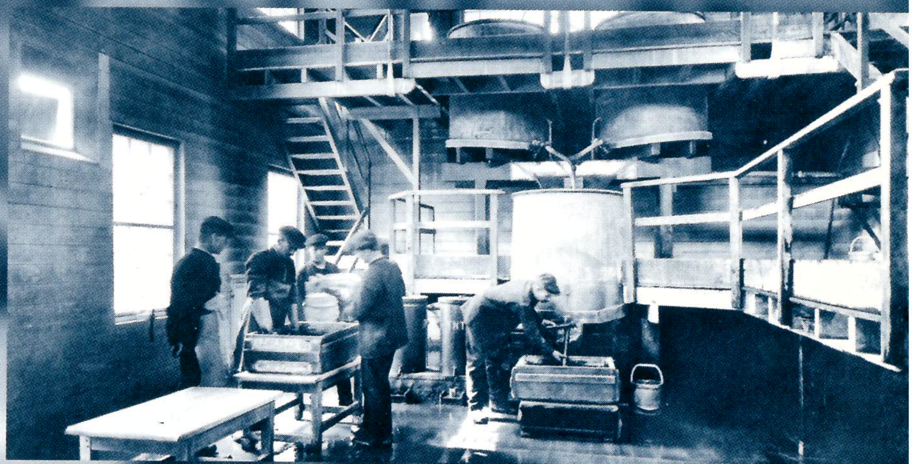
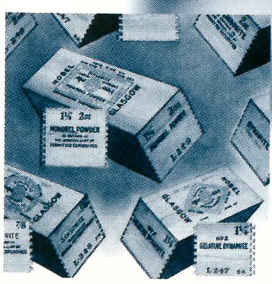
Ardeer and The Nobel Heritage





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Explosives
in the service of man
Ardeer and The Nobel Heritage

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Alfred NOBEL'S EXPLOSIVES COMPANY TRADE MARK LIMITED. Nobel

GLASGOW

Preface

In the world of Chemistry, and for the explosives industry in particular, 1996 is a notable year. It is the centenary of the death on 10 December 1896 of Alfred Nobel, the founder both of the modern explosives industry, and the internationally famous Nobel Prizes. It is also the one-hundred and twenty-fifth anniversary of the foundation by Nobel of the Ardeer factory, which was the United Kingdom's first Dynamite factory. In addition, it is the seventieth anniversary of the formation in 1926 of the giant chemical company, Imperial Chemical Industries (ICI), the ultimate achievement of the company which Nobel had founded on the west coast of Scotland fifty-five years earlier.

Today, such is the international fame of Alfred Nobel that the learned Societies associated with Chemistry and the Science and Technology of Explosives in the United Kingdom deemed that they should pay proper tribute to the great man on this unique occasion by holding a conference on the Science of Explosives and a banquet in his honour on the day of the centenary which, coincidentally, is the day on which the year's Nobel Prizes are to be presented in Sweden.

Through the publication of this book, the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) and ICI Explosives wish to take the opportunity that the Nobel Heritage Conference offers to pay their own modest tribute, thereby acknowledging the debt that Scotland, the United Kingdom and the World owes to Alfred Bernhard Nobel.

Authors

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Acknowledgements

The authors would like to take this opportunity to thank the many people who have assisted in the production of this book. They are particularly grateful to ICI Explosives for their generous financial support, without which the project would not have been possible. At Ardeer, special thanks are due, both for their professional guidance on the ground and their continuing support, to Jack Pearson, Vernon Parker, Peter Cartwright, Joe Herring, Alan Gray, Campbell Howie, Margaret Magee (for letting us past the front gates), Gary Hemingway, John Davidson, George Fowlie and Mark Wyllie. In addition, the assistance provided by Annette Kelly and Sheila Conway on the archives side has been especially significant, as was the initial help provided by Sandy Profit in Wales and Ted Patterson in West Kilbride. Further afield, the guidance of Tony Weale at ICI Headquarters has also been appreciated, as was the help received from Brian Harris, Alan Clements and Claire Louise Bean.

At RCAHMS, work on the early archive material by Tahra Duncan, Derek Smart and Stephen Thomson of the Photography Department has been particularly important, as has the production of the maps by Kevin MacLeod. Survey work at Ardeer by Jim Mackie and Graham Douglas has also proved to be very valuable. Editorial assistance and encouragement from colleagues, including Roger Mercer, Geoffrey Stell and Miriam McDonald, has been greatly appreciated, and production would not have been possible without the work of John Stevenson and Kate George in the Publications Section. Finally, much of the impetus behind the RCAHMS initiative at Ardeer was provided by the initial approaches of the Gunpowder Mills Study Group in 1990. Their continuing interest, and the support of our sister Royal Commissions in Wales and England have been greatly appreciated.

November 1996

Figure 1: Painting of the Ardeer Factory by Henry Rushbury, R A, published by ICI in 1958 (C 47356)

In 1871, Alfred Nobel brought the newly-born high-explosives industry to Britain, establishing with the backing of Scottish entrepreneurs, the country's first Dynamite factory at Ardeer on the west coast of Scotland in Ayrshire [Figure 1]. Ardeer grew to become the largest explosives factory in the world, and as well as being one of the principal driving forces behind the creation of ICI in 1926, transformed the surrounding area, leading to the expansion and prosperity of the neighbouring towns of Stevenston, Saltcoats, Kilwinnning, Ardrossan and Irvine.

In addition to the immense local economic and social importance of Ardeer, the factory has played a major part in the continued prosperity of Nobels Explosives and ICI as a whole. The development of a wide range of high explosives has revolutionised the mining and engineering industries, thereby not only helping to supply industries throughout the world with essential minerals and raw materials, but also assisting vital infrastructural projects such as harbours, canals, railways, roads and water and electricity supplies. As a major research centre for ICI, Ardeer has also developed a bewildering range of new, non-explosives products, spawning new divisions of the company.

As the end of the millennium approaches, so Ardeer's fortunes have gradually declined, a trend recently accelerated by the rapid contraction of the British deep coal-mining industry. In addition, changes in the pattern of international trade of high-explosives, and competition from alternative products, have led to the rationalisation and closure of large parts of the factory.

In order to ensure that the immense contribution of Ardeer is recognised, and that a proper record is retained of the achievements and history of the factory, ICI Explosives is working closely with the RCAHMS and the Scottish Record Office. In addition to selective survey work within the factory, attention is being paid to the collection and safe storage of historical archive material.

As well as paying tribute to Alfred Nobel in this centenary year, the purpose of this book is to acknowledge the contribution of the Ardeer factory both to the local area and the world as a whole. In so doing, the book relies upon a blend of historical material retrieved from ICI Explosives archives at the factory, and from recent survey activities carried out by RCAHMS since 1990.

Although this is essentially a simple story, some of the terms used are unavoidably technical. A glossary has therefore been compiled to assist with some of the more specialised terminology, and is situated alongside a bibliography containing reference sources at the end of the volume.

Nobel's sporting cartridges
(ICI Explosives, 1907)

The Industrial Revolution of the 18th and 19th centuries saw the birth of the modern age of technology, the key to which is power. Within this millennium, power has been obtained from the movement of water and air, from the sun, and from a variety of fuels ranging from coal, oil and gas to plutonium. Within this array of power sources, that obtainable from chemical energy in the form of high explosives continues to be one of the most dramatic. However, despite the apparent sophistication of modern explosives, it is important to recognise that this energy is fundamentally a form of **Fire**, the oldest form of energy known to man. The science of the explosives technologist, in principle, consists of taking this combustion reaction and speeding it up to the point where it takes place faster than the speed of sound and, in the process, produces a high-intensity shock wave which can be used in mining and for a wide variety of engineering purposes. [1]

The first step towards an explosives technology was taken thousands of years ago when it was accidentally discovered that certain solid materials (nitrates) could replace the oxygen gas in air within the combustion process, and that such solid mixtures, when ignited and confined, reacted violently with devastating effect. This discovery was made without any knowledge of the 'riotous' chemistry involved, the resulting explosives evolving into what was referred to as blackpowder.

The exact origins of blackpowder are unclear, although it was reputedly invented by the Chinese, possibly over 3,000 years ago. One of the first clear references to the practical use of blackpowder was that of Marcus Graecus in the 7th century AD, who recorded its use in crude rockets as siege weaponry. The first recorded use for blasting in mining or quarrying, however, is not until as late as the seventeenth century.

Prior to 1860, the use of chemical energy as a means of reducing the physical workload in mining and civil engineering projects was limited to those tasks which could reliably be performed by blackpowder, which, being a reaction between two separate chemicals, burns to detonation and is, by that definition, a deflagrating, low explosive. The breakthrough to modern detonating high explosives came with the discovery by the Italian chemist Ascanio Sobrero in 1846 of a chemical entity which could replace the low explosive mixture of chemicals with a single molecular substance, Nitro-glycerine.

For Sobrero, the damage to his laboratory following his discovery of Nitro-glycerine demonstrated both the power of the substance and its hazardous unpredictable nature. The dangers associated with handling Nitro-glycerine, and the difficulty of achieving a reliable, effective and deliberate detonation, subsequently ensured that it remained a laboratory curiosity for many years.
It was the work of the Nobel family that was to bring about its transformation into an exploitable commercial explosive. This was made possible by what was probably the greatest single development in the history of high explosives, when Alfred Nobel invented the detonator. Its initial form comprised blackpowder in a sealed tube, which acted as a comparatively safe and reliable means of initiating detonation in the main charge of nitro-glycerine.

After 1864, therefore, the availability of detonators permitted the use of Nitro-glycerine as 'Blasting Oil' for a wide variety of uses. However, it was extremely sensitive, very hazardous to transport, and particularly dangerous to handle in cold conditions. In addition to catastrophic accidents that occurred during its manufacture, disaster frequently struck when in transit, or during its use on site, where it proved to be awkward to apply (being a liquid). In many countries, the manufacture, use and transport of Nitro-glycerine was viewed with alarm, and was banned by law.

The key to the successful exploitation of Nitro-glycerine was therefore the development of a means by which it could be made safe to transport and to handle, and it was again Alfred Nobel who achieved this in 1866, with his ingenious discovery that by mixing it with an 'infusiorial earth' called Kieselguhr, it could be handled and applied entirely safely.

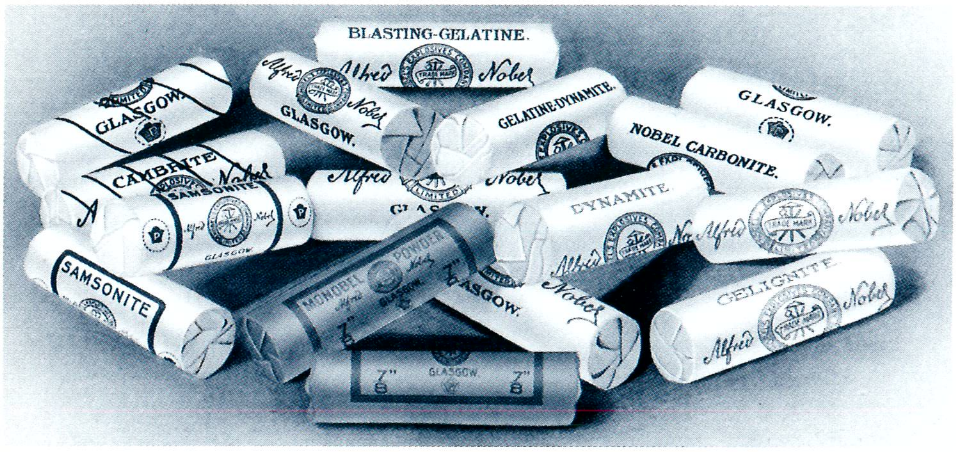


Figure 2: Illustration showing brands of Nobel cartridges of blasting explosives (Nobel's Explosives 1907, C65817)

In doing so, Nobel had created the first and perhaps the most famous of high explosives, which he named 'Dynamite' after the Greek word 'dynamis', meaning power. The term 'Dynamite' has since become almost synonymous with explosives.

Taming the dangerous properties of nitro-glycerine by absorbing it on the inert kieselghur suffered from the disadvantage that it also reduced the power of the explosive. This Nobel sought to rectify by using nitro-cellulose (itself an explosive) to replace the kieselguhr as an absorbent, the combination eventually producing 'Blasting Gelatine' in 1875, which remains even today, the most powerful and waterproof commercial explosive available.

Dynamite itself was gradually superseded by a range of explosives the power and brisance of which was varied by mixing varying quantities of nitro-glycerine with fuel/nitrate mixtures, leading to the emergence of the three broad classes of Powders, Semi-gelatines and Gelatines. This technique enabled the production of a range of tailor-made explosives with specific powers and velocities of detonation to suit the varied requirements of the civil and mining engineer. Examples include highly brisant explosives for working hard rock blasting such as tunnelling, and less brisant explosives for blasting coal and decorative stone where a more gentle heaving action is required.

One important range of specialist explosives was 'Permitted Explosives', which were first recognised in 1896, and were designed for safe use in gassy coal mines where there was a danger of explosion due to the presence of methane gas and coal dust. Permitted explosives are lower-powered explosives comprising smaller percentages of nitro-glycerine and containing flame-suppressants designed to inoculate the gassy atmosphere and minimise the risk of accidental explosions.[2]

Inevitably, Nitro-glycerine was seen as having great potential for use in propellants, and Nobel's fourth major development involved the invention of improved propellants. Applying the same principles as in blasting gelatine, but increasing the quantities of nitro-cellulose and adding camphor, he produced a Nitro-glycerine based propellant which he patented in 1888 under the name of 'Ballistite'. Nobel's work stimulated investigation by others into variations on these principles, resulting in the development of Cordite which he believed infringed his patent rights for Ballistite. Unfortunately, the wording of his original patent specification led to an adverse decision in an ensuing court case. The experience moulded Nobel's opinion of lawyers, about whom he said,

'Lawyers have to make a living and can do so only by inducing people to believe that a straight line is crooked. This accounts for

their penchant for politics where they can usually find everything so crooked enough to delight their hearts'.[3]

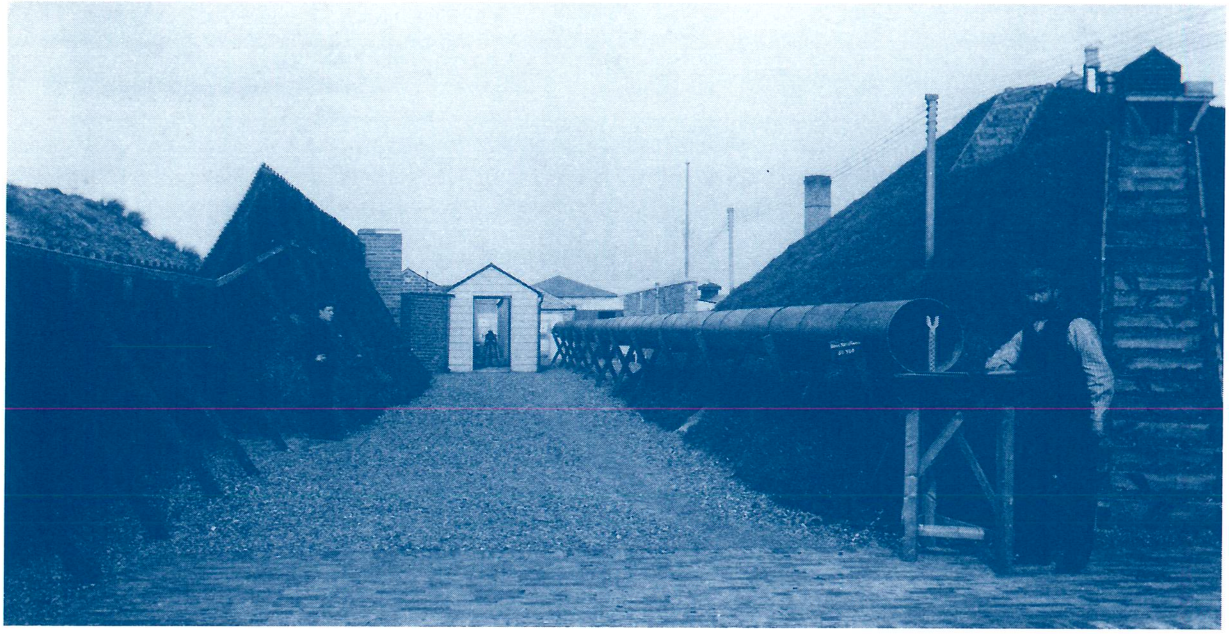
Despite this setback, Cordite manufacture later emerged as a significant activity at Ardeer, particularly during the war years.

In summary, it is clear that the critical period of development occurred in the 50 years between 1846 and 1896 (see table below). After Sobrero's discovery of Nitro-glycerine in 1846, a sequence of other inventions, including, TNT and Picric Acid were also immensely significant, but Nobel's detonator, Dynamite, Blasting Gelatine and propellants had the greatest impact, especially outside the military sphere.

Indeed, it is the development of blasting explosives for which Nobel is most famous. Through his inventions, he revolutionised the mining and civil engineering industries, heralding the beginning of the modern explosives era. Today, the use of sophisticated explosives and devices arising from his pioneering work has, in addition to world-wide use in the mining and quarrying industries, been extended to embrace an immense variety of engineering applications. These include civil infrastructure engineering operations of all kinds; underwater blasting operations; seismic exploration and exploitation of oil and gas reserves (both onshore and offshore); explosive shaped cutting charges; explosive bolts; explosive welding and metal forming; explosive fire-suppressant safety systems; aircraft pilot ejector seats; automobile passive restraint systems (air bags!); and the Space Programme (both for lift-off and in-flight control systems).

Significant Dates in Explosives Development [4]

Date	Associated Person	Explosive
?	Blackpowder	
1242	Bacon	Gunpowder
1831	Bickford	Safety Fuse
1832	Braconnot	Nitrated Starch (Xyloidine)
1838	Pelouze	Nitro-cellulose (Pyroxyline)
1845	Schonbein	Guncotton
1847	Sobrero	Nitro-glycerine
1862/4?	Nobel	The Detonator
1863	Wilbrand	TNT
1866	Nobel	Dynamite
1871	Sprengel	Picric Acid
1875	Nobel	Blasting Gelatine
1885	Vielle	Nitro-cellulose Powder
1888	Nobel	Ballistite
1896		Permitted Explosives officially recognised



Outer part of Test Range at Ardeer (ICI Explosives, C62960)

Plate 1: Portrait of Alfred Nobel, 1833-1896 (ICI Explosives, C62967)

Alfred Nobel [Plate 1] was born in Sweden in 1833, much of his childhood being spent in comparative poverty and poor health.[5] When four years old, his father Emmanuel, himself an engineer and inventor of note with an interest in explosives, was forced by straitened circumstances and eventual bankruptcy to emigrate to Finland and then to Russia. At first, Alfred remained with his family in Sweden facing a desperate struggle to survive, but at the age of nine, his father's fortunes had revived sufficiently for the family to join their father in Russia. Seven years later, in 1849, Alfred was sent to the USA to study under John Ericson, the famous Swedish engineer, returning four years on to resume the family's experiments with explosives. However, tragedy struck in 1864 when his youngest brother, Emil, was killed at the age of 20 in an explosion at his father's experimental workshop in Heleneborg during early attempts to manufacture Nitro-glycerine. Although his father never recovered, the tragedy failed to deter Alfred, who continued his pioneering work with Nitro-glycerine.

It is often not realised that as a result of this disturbed childhood, Nobel had little or no formal education. There was no Swedish school in St Petersburg, and the laws in Russia concerning immigrants were very strict at the time, preventing Nobel from attending formal school and university. In spite of this, he became an inventor of outstanding ability and was responsible for over 355 inventions,[6] including not only the explosives, detonators and propellants for which he is internationally renowned, but also such materials as celluloid film and artificial silk, and also biochemical studies of blood.[7] In addition, he established and controlled fifteen major manufacturing companies throughout Europe and the United States before he had reached the age of forty (see table below). In the process, he covered enormous distances in a travel schedule of which a modern business man would be proud, and all this in an era without motor cars or aeroplanes.

NOBEL FACTORIES 1865-73 [8]

Sweden (Winterviken)	1865
Germany	1865
Norway	1866
Austria/Czechoslovakia	1866
Finland	1870
Scotland	1871
France	1871
Spain	1873
Switzerland	1873
Italy	1873
Portugal	1873
Hungary	1873

Note that Nitro-glycerine manufacture was patented in the USA in 1865 and first produced by the US Blasting Oil Company of New Jersey. Dynamite was patented in the US in 1867 and manufactured by the Giant Powder Co. in 1870, but not under the Nobel banner.

Much of the world expansion that occurred after 1873 was under the auspices of Nobel's Explosives Company (Scotland), and included major establishments in South Africa, Canada, Japan and Belgium

He had managed, meanwhile, to teach himself six languages, and was fluent in three. His methods in these achievements were unusual, and provide an insight into the dedication and determination to achieve perfection which was to rule his life. For example, he perfected his command of French syntax by translating Voltaire into Swedish and then translating it back into French in order to compare his understanding of idiomatic French with that of the author.

As his exercises with Voltaire suggest, Nobel's intellectual interests extended well beyond the sciences, embracing literature. Indeed, he was a poet of some merit, writing some remarkable verse at an early age, later diversifying into drama, writing a three-act play. Although these works were not published, he never lost his love of literature, and was writing a book at the time of his death in an attempt to achieve a lifetime ambition of becoming an author.

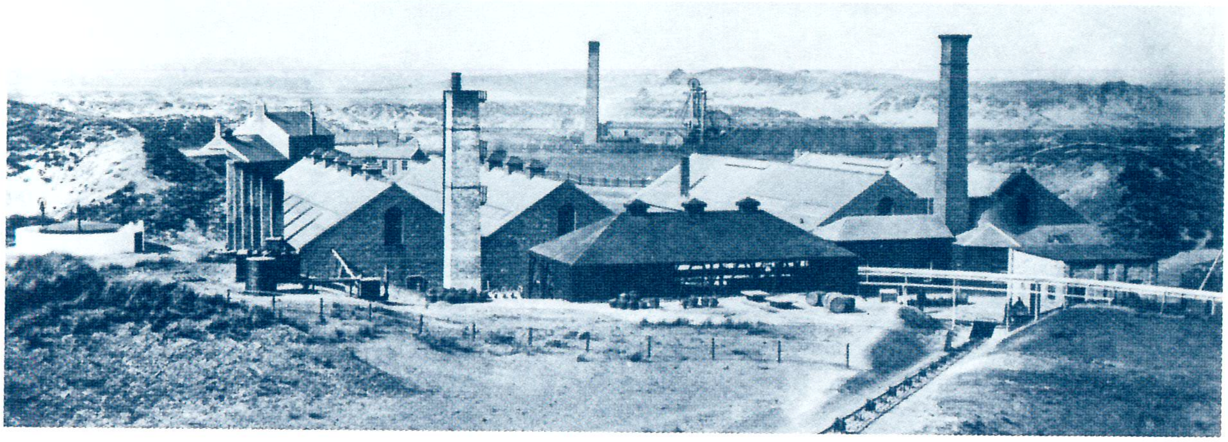
It is through these interests that it is possible to see the roots of his legacy of international Nobel prizes for Peace, Physics, Chemistry, Medicine and Literature.[9] However, his genius was at a very basic level, lying not in fundamental discoveries, but as an intensely practical experimenter with an extraordinary ability to find simple solutions to other people's problems. He was fuelled by an insatiable curiosity and imagination, his approach being well encapsulated in his own words, 'If I have a thousand ideas in a year and only one turns out to be good, I'm satisfied'.[10]

Nobel never married and never settled down, wandering from country to country, acquiring the name of 'The Richest Vagabond in Europe'.[11] He was a lonely man who never seemed to make any real friends. He had, however, a close affinity with Scotland, and it was in Glasgow that he found the kindred entrepreneurial spirit that enabled him, at the age of 37, to overcome the obstacles that had hindered his attempts to establish his industry in the United Kingdom, establishing the British Dynamite Company's factory at Ardeer on the Firth of Clyde in 1871.

During his lifetime, Nobel saw his infant company rise to greatness and transform the bleak and then still sparsely populated area of the three towns of Stevenston, Kilwinning and Saltcoats into a burgeoning hive of industry and acknowledged business excellence. By the time of his death in 1896, his Scottish company was supplying one tenth of the world's need of explosives, and was growing to dominate the world of explosives in terms of export, research and development.[12]

Plate 2: General view of original Ardeer Factory from Nitro-glycerine Hill, circa 1880, showing boiler and engine houses, nitric acid plant, and Lucknow Colliery in background. There were a number of colliery shafts within the factory (ICI Explosives, C62968)

Yours very truly
Alfred Nobel



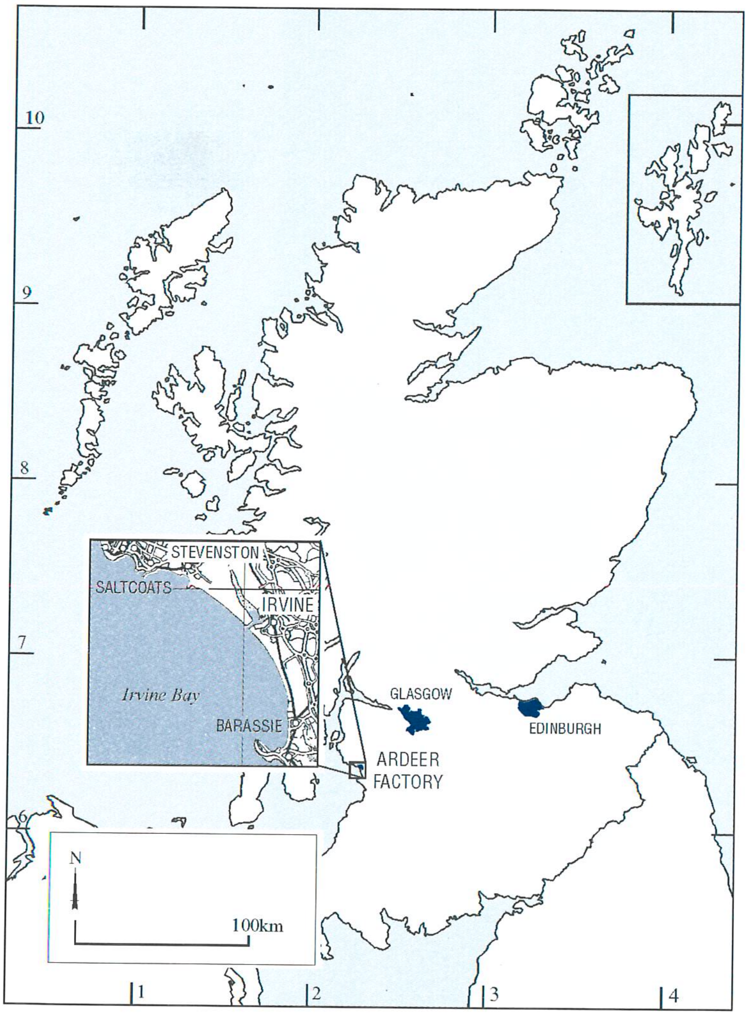


Figure 3: Outline map of Scotland, showing the location of Ardeer in a national context, © Crown Copyright

Unlike most inventors, Alfred Nobel combined technical creativity with commercial flair, and both to a very high degree. A lack of capital proved to be no hindrance, and having borrowed it, he had within a few years founded an international group of Dynamite companies in Scandinavia and Germany. He then turned his attention to the United States of America, Great Britain and the rest of Europe.[13]

Although potentially very lucrative, Nobel found Great Britain the most difficult of countries in which to deal, mainly for political reasons relating to safety legislation. After serious accidents with Nitro-glycerine in different parts of the world, the British Government emulated other countries such as Belgium, passing an Act of Parliament in 1869 which forbade, '...the manufacture, import, sale and transport of Nitro-glycerine and any substance containing it within Great Britain.' Nobel spent two frustrating years before he was able persuade the authorities of the efficacy and safety of Dynamite, inducing a reluctant easing of the strict regulations, although even then he was unable to obtain permission to establish his business in England. Eventually, he turned to Scotland [Figure 3], where he found a receptive group of entrepreneurs. With their help, principally assisted by John Downie of Fairfield Shipbuilding who became Manager and Secretary, he set up a company and a factory site at Ardeer in April 1871 with the rights to work his patents under the name of The British Dynamite Company.

The factory [Plate 2] was designed by Dr P A Liedbeck, the engineer who managed Nobel's first factory at Winterviken in Sweden, and therefore benefited substantially from the experience already acquired from Nobel's earlier establishments. The equipment installed was a considerable improvement on the early systems, particularly with respect to the glycerine nitration and Dynamite cartridging processes. Indeed, the batch nitration process with its one-legged stool (to prevent the operator from falling asleep and failing to detect potentially fatal rises in temperature) is now almost a Logotype for Dynamite manufacture [Plate 3]. The first 1,500 lb charge of Nitro-glycerine was produced on 13 January 1873, and the first batch of Dynamite mixed later that year. Four

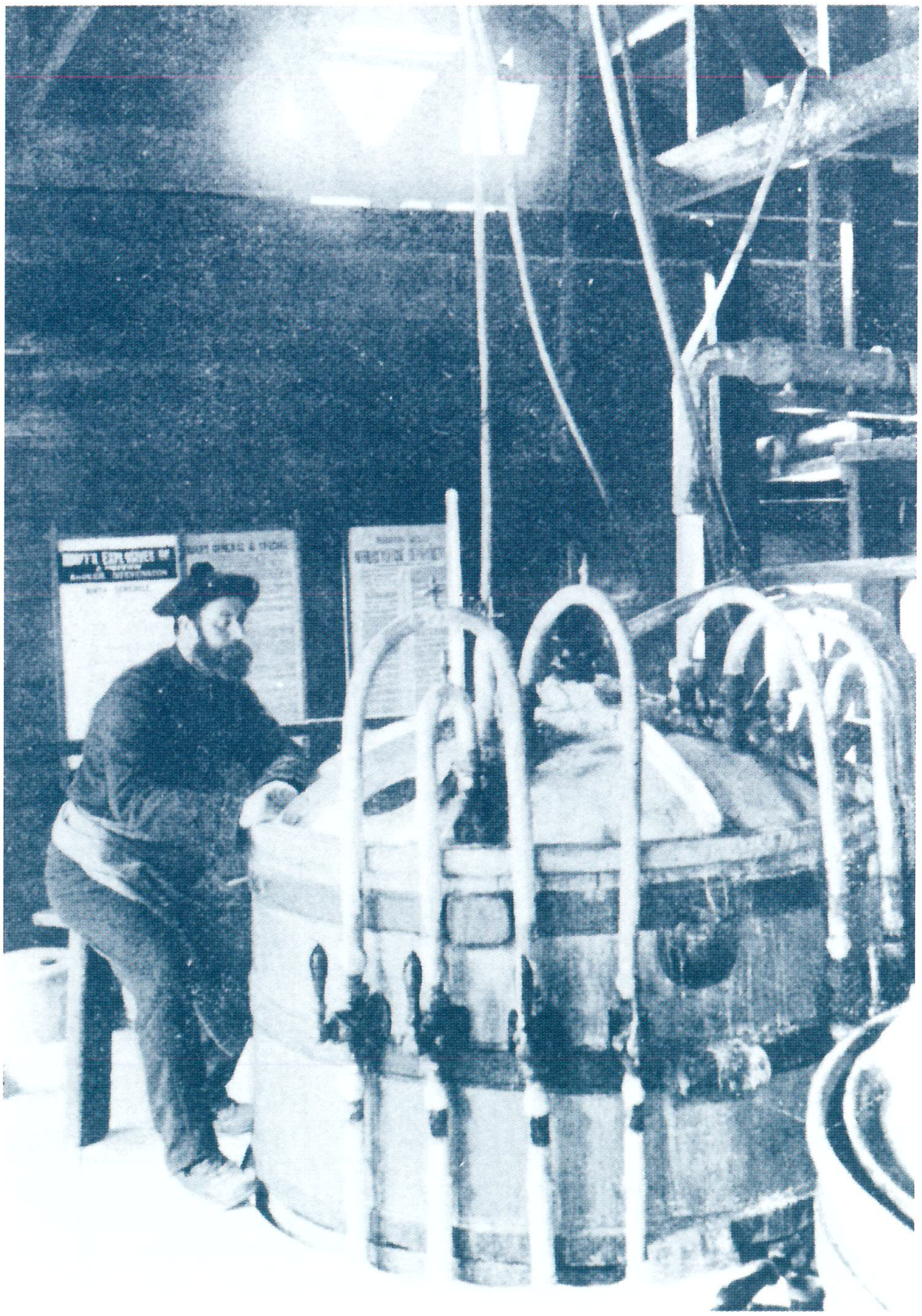
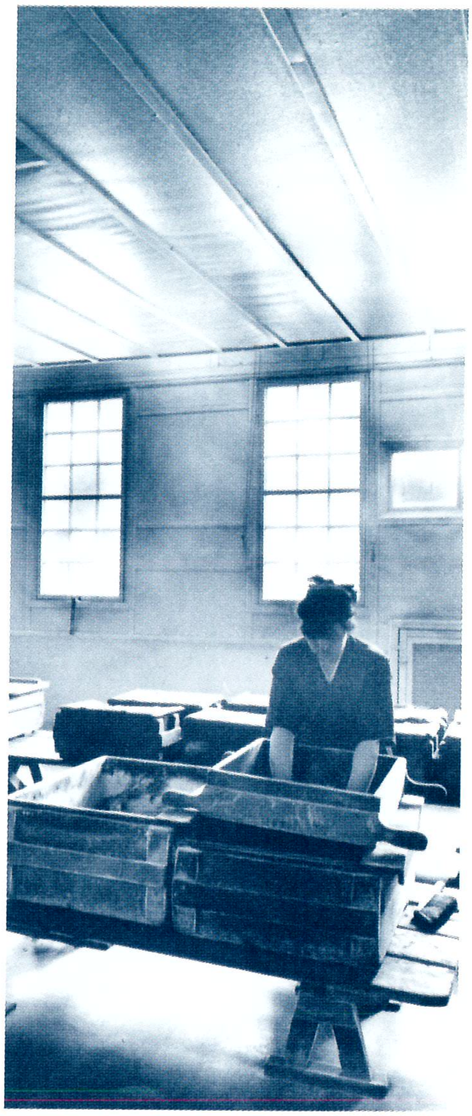


Plate 3: Early illustration showing nitro-glycerine nitrator and operator, sat on one-legged stool. The process of nitrating glycerine is exothermic, creating heat, and required the circulation of cooling water to maintain a safe temperature. The one-legged stool was therefore a safety device designed to prevent the operator from falling asleep, thereby ensuring that he paid close attention to the thermometer (ICI Explosives, C65821)

Plate 4: Detailed view inside Dynamite Mixing House showing hand-mixing, circa 1880. One of Nobel's greatest inventions was the creation of Dynamite by mixing nitro-glycerine on absorbent earth known as kieselguhr, a process which transformed the nitro-glycerine from an extremely hazardous oily liquid into a safe high explosive. Prior to the introduction of mechanised mixing, the production of high explosives from nitro-glycerine involved hand mixing, as shown here (ICI Explosives, C47086)

years later, the name of the company was changed to become the Nobel's Explosives Company.



The kieselguhr with which the Nitro-glycerine was initially hand-mixed to produce Dynamite [Plate 4] was found principally in Germany and Scotland. Potential sources included the diatomite deposits at Loch Cuithir on the Isle of Skye, but deposits in Aberdeenshire were eventually preferred.[14] The supply of acid for the nitration process was first obtained from the Westquarter Chemical Company near Falkirk (later to become Nobel's detonator factory), one of whose partners, McRoberts, joined the British Dynamite Company in 1874, becoming Chief Chemist and eventually Manager. McRoberts' name has since become synonymous with the design of early gelatine mixing and cartridging machinery, some of which is still in use today.

The company prospered during the 1880s, developing an impressive overseas trade, and had by the time of Nobel's death become the largest exporter of explosives in the world. This had been achieved through the diversification into and development of new products, including Blasting Gelatine (1879), Gelignite (1881), Ballistite (1887), Guncotton (1892) and Cordite (1895). Product innovation was particularly significant in the field of safety explosives for use in dangerous gassy coal mines, underwater explosives and devices, new types of detonator, detonating fuse, safety fuses of all varieties, and propellants.

The factory continued to grow after Nobel's death, expanding from the original 100 acres (40 hectares) to over 2,000 acres (over 800 hectares, or over 3 square miles), the number of employees swelling from 50 to a peak of

Plate 6: View of SS Lady Gertrude and SS Lady Dorothy, both explosives-carrying steamers belonging to Nobel's Explosives, circa 1925. Much of Ardeer's production was destined for export, and even for British markets, the safest and most efficient means of transport was by sea (ICI Explosives, C65562)

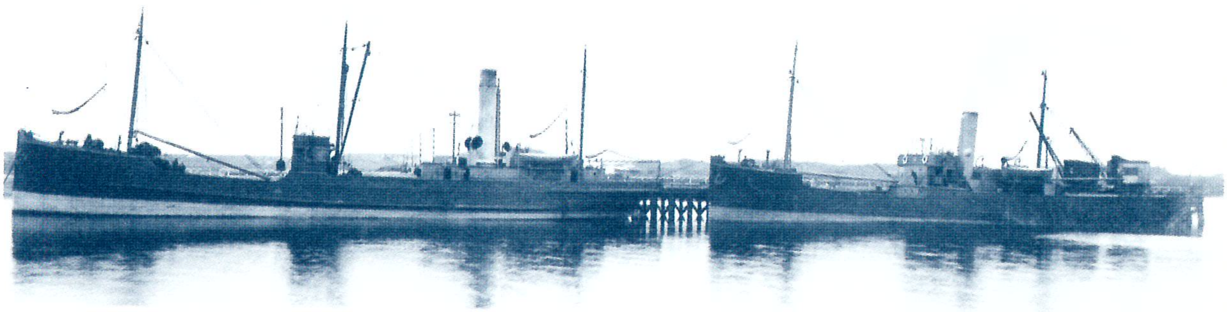


Plate 5: View within Ardeer Factory of nitric acid plant, with nitro-glycerine hill to right in background, and gas works in foreground, circa 1880. (ICI Explosives, C62977)

13,000. The range of manufacturing activities also grew rapidly, eventually satisfying all its own requirements for gas, acids, ammonium nitrate and other components [Plate 5], importing only the very basic of raw materials, and having an enviable independence from outside contract trades. The infrastructure was equally impressive, the site having its own power station, road and narrow-gauge railway networks, and direct national rail links and marshalling yards. In later years, new production capacity for the manufacture of blackpowder, safety fuse and detonators expanded the factory still further.

The export trade was greatly facilitated by the acquisition of the harbour facilities at Irvine with quayside-loading for coasters. The sea access was fully exploited first by the labour-intensive process of loading from the beach into the sailing vessel , 'The Jeannie' (named after McRoberts' wife). In subsequent years, a succession of explosives steamers was acquired or built to serve overseas trade, each, with one exception, named after the wives of company dignitaries, and included The Lady Gertrude Cochran, The Lady Tennant, The Lady Anstruther, The Lady Dorothy, The Lady McGowan, and The Lady Helen [Plate 6, page 19]. The exception was a boat eventually named after Alfred Nobel himself, but not in his lifetime because he protested that a ship was a 'She' and not a 'He', adding that, '...she is in any case much too elegant to be named after an old wreck like me.'[15]

In due course, Ardeer became the centre of excellence in explosives research,[16] and later the research centre for ICI, spawning entirely new divisions of the company. The brief list below provides a rough idea of the huge range of other products that have emanated from Ardeer during its 125 years of production: Leather Cloth; Nitro-cellulose Automotive Paints; Benzyl Cellulose; Celluloid Films; Ethers and Esters of Cellulose; Methyl Cellulose Ethers - Cellofas; Edible Derivatives of Cellulose - Edifas; Glycerine Fermentation; Methane Gas Production by bacterial decomposition; Biochemical Development in moulds; Diesel Improvers; Flexel Heating Films; Acrylics; Melinex Films; Ardil Fibre - artificial wool;[17] Pesticidal Smokes[18] - (Gammexane). One of the most important parts of the factory was the Library, at the heart of which were the filing cabinets containing the index cards linking references to reports, technical books and journals for the benefit of the company's research chemists [Plate 7].

Plate 7: Interior view within the Library at Ardeer, showing the Index Cards, Annette Kelly (Information Officer), and Sheila Conway (former Records and Reports Officer), 1995, (RCAHMS, C64396)

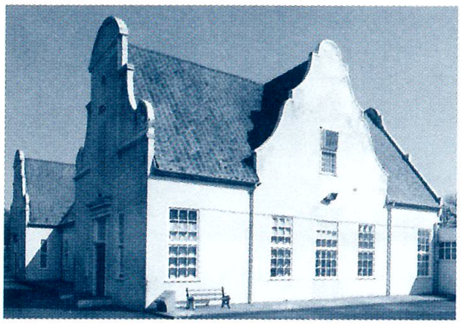
Even the shortest of histories of Ardeer would not be complete without mention of its greatest asset - its workforce. Successive generations of Ayrshire people have been Dynamite men and women, and have taken their expertise all over the world. It was teams from Ardeer that built and commissioned plants in India, the Philippines, Hong Kong, and more recently, Ghana and Thailand. Ayrshire people have therefore taken their traditions and Scottish humour to these and other distant parts of the world, often leaving behind a curious blend of cultures, more often than not including Burns Suppers, to become a part of local folklore.

Figure 4: Artist's impression of the air raid by the Luftwaffe in May 1941. On the night, the factory escaped serious harm, suffering little damage and one fatality (Campbell Howie)

It was inevitable that Ardeer played a very substantial role during the Second World War when, between Ardeer and the nearby Royal Ordnance and Ministry of Defence factories at Irvine, Bishopton and Powfoot, the West of Scotland had some 30,000 of its people engaged in active support of munitions production for the war effort. Its importance was clearly recognised by German military intelligence, as is confirmed by Luftwaffe photographs taken in January 1941 [Plate 8]. It is therefore surprising that only one air raid was effected, causing remarkably little real damage [Figure 4]. This occurred on 7 May 1941, the bombers apparently locating the factory by following the firebox of the steam locomotive pulling the nightshift workers' train as it approached the site. Perhaps the greatest concern was caused by some incendiary bombs, which set light to the vegetation, the blaze subsequently being contained, during the course of which one life was lost. Fortunately, the high-explosive bombs that found their target failed to explode, and after they had been located, disarmed, and removed, workers at the factory were invited to see them for one penny a time, the proceeds being given to the Red Cross.

It is appropriate that, given Nobel's own intense interest in people, and his reforming approach on social matters, this spirit was maintained in Ardeer with the provision of welfare facilities, recreation clubs, golf courses, tennis courts and a wide range of community activities. It is also significant that, throughout its existence, the Ardeer factory has been remarkably strike-free. Sadly, although the factory had an exemplary safety record which exceeded that of many conventional industries, accidents did occur on occasion, and lives were lost.[19] The fact that they occurred as infrequently as they did is a testament both to the company's rigorous implementation of safety rules and regulations as well as the skill and quality of the workforce.

Meanwhile, the enduring international significance of Ardeer is perhaps best symbolised by the translocation to Ardeer from Bellahouston Park in Glasgow of the 1938



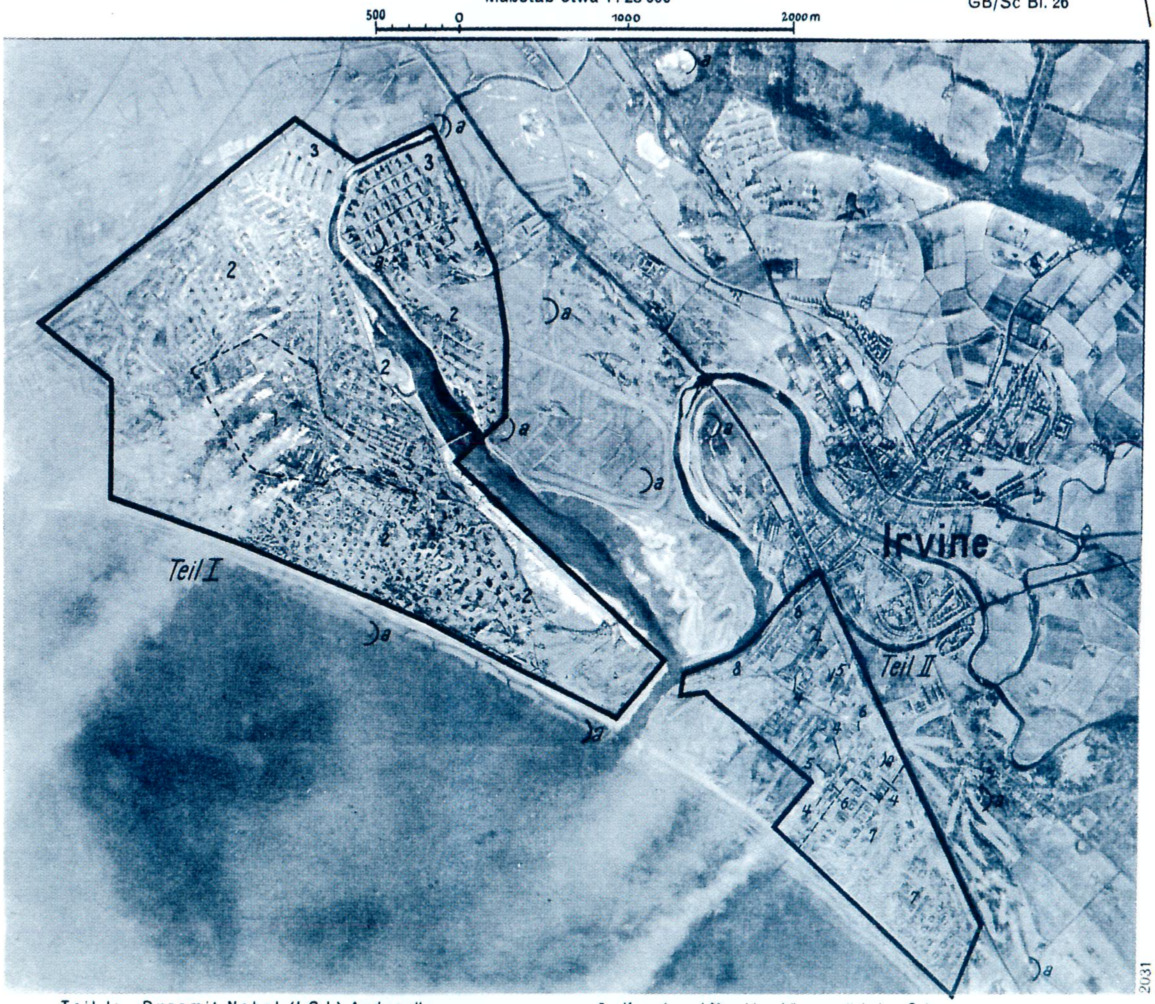
Empire Exhibition South African Pavilion, which was converted into a staff restaurant [Plate 9]. Africa House, as it has subsequently become known, bears more than a passing resemblance to the company guest house at Monderfontaine in South Africa, and has been designated a listed building by Historic Scotland.

Plate 9: (left) Exterior view from north of Nobel's Explosives staff canteen, re-named Africa House, formerly the South African Pavilion at Glasgow's Empire Exhibition in Bellahouston Park in 1938. The building was moved to Ardeer where it was converted for use as a staff canteen. 1990 (RCAHMS, B41104)

GB 768 b c
Nur für den Dienstgebrauch
Bild Nr. 12/41-043 (v.) Lfl. 5
Aufnahme vom 9. 1. 41

Irvine
Sprengstoffwerke
Länge (westl. Greenw.): 4° 42′ 07″ Nördl. Breite: 55° 36′ 55″
Mißweisung: — 13° 50′ (Mitte 1940) Zielhöhe über NN 15 m
Maßstab etwa 1 : 28 000

Luftwaffenführungsstab Ic/II
März 1941
Karte 1 : 100 000
GB/Sc Bl. 26



Teil I: „Dynamit Nobel (I.C.I.) Ardeer":

1. Sprengstoffverarbeitender Teil, massive Werkgebäude (Füllanstalten), versch. Dacharten, Kessel- u. Maschinenhäuser mit Schornsteinen — zus. etwa 48 000 qm
2. Sprengstofflagernder Teil, etwa 170 umwallte Munitionshäuser — zus. etwa 52 000 qm
3. Lagergebäude, 41 Gebäude — zus. etwa 31 000 qm

Teil II: „Royal Ordnance Factory Irvine":

4. Massive Werkgebäude (Herstellung von Salpetersäuren und Trinitrotoluol), versch. Dacharten — zus. etwa 22 000 qm
5. Kessel- und Maschinenhäuser mit hohen Schornsteinen — etwa 2 700 qm
6. 12 Salpeterbehälter (Durchmesser etwa 8 u. 14 m)
7. Etwa 25 umwallte Lagergebäude (Lagerung explosiver Stoffe — zus. etwa 22 000 qm
8. Verwaltungs- u. Wohngebäude, massiv, verschiedene Dacharten — zus. etwa 9 200 qm

Bebaute Flache etwa 186 900 qm
Gesamte Flache etwa 7 900 000 qm

a) Sperrballone — Gleisanschluß vorhanden

Plate 8: (left below) Vertical aerial view of the Ardeer Factory and surrounding area, taken by the Luftwaffe in 1941 prior to the air raid (RCAHMS, C 47643)

Plate 10: Oblique aerial view from west over centre of factory in 1992, providing an idea of the scale and complexity of the site (RCAHMS, B72163)

Today, the Ardeer factory covers an area of approximately three square miles (over 2,000 acres) within which there are many hundreds of buildings [Plate 10]. At its foundation in 1871, the British Dynamite Company began with a plot of only 100 acres, but as the map in Figure 5 indicates, expansion was rapid, and by 1907, Nobels described Ardeer as the largest explosives factory in the world. Subsequent expansions enveloped land to the north and the east, crossing the River Garnock, the company even acquiring the Bogside Racecourse, once the venue for the Scottish Grand National.

The Ardeer site proved to be ideally suited to the manufacture of high explosives. When Alfred Nobel moved to the area in 1871, he described it vividly in a letter to his brother.

'*Picture to yourself everlasting bleak sand dunes with no buildings. Only rabbits find a little nourishment here; they eat a substance which, quite unjustifiably goes by the name of grass. It is a sand desert where the wind always blows, often howls, filling the ears with sand. Between us and America there is nothing but water, a sea whose mighty waves*

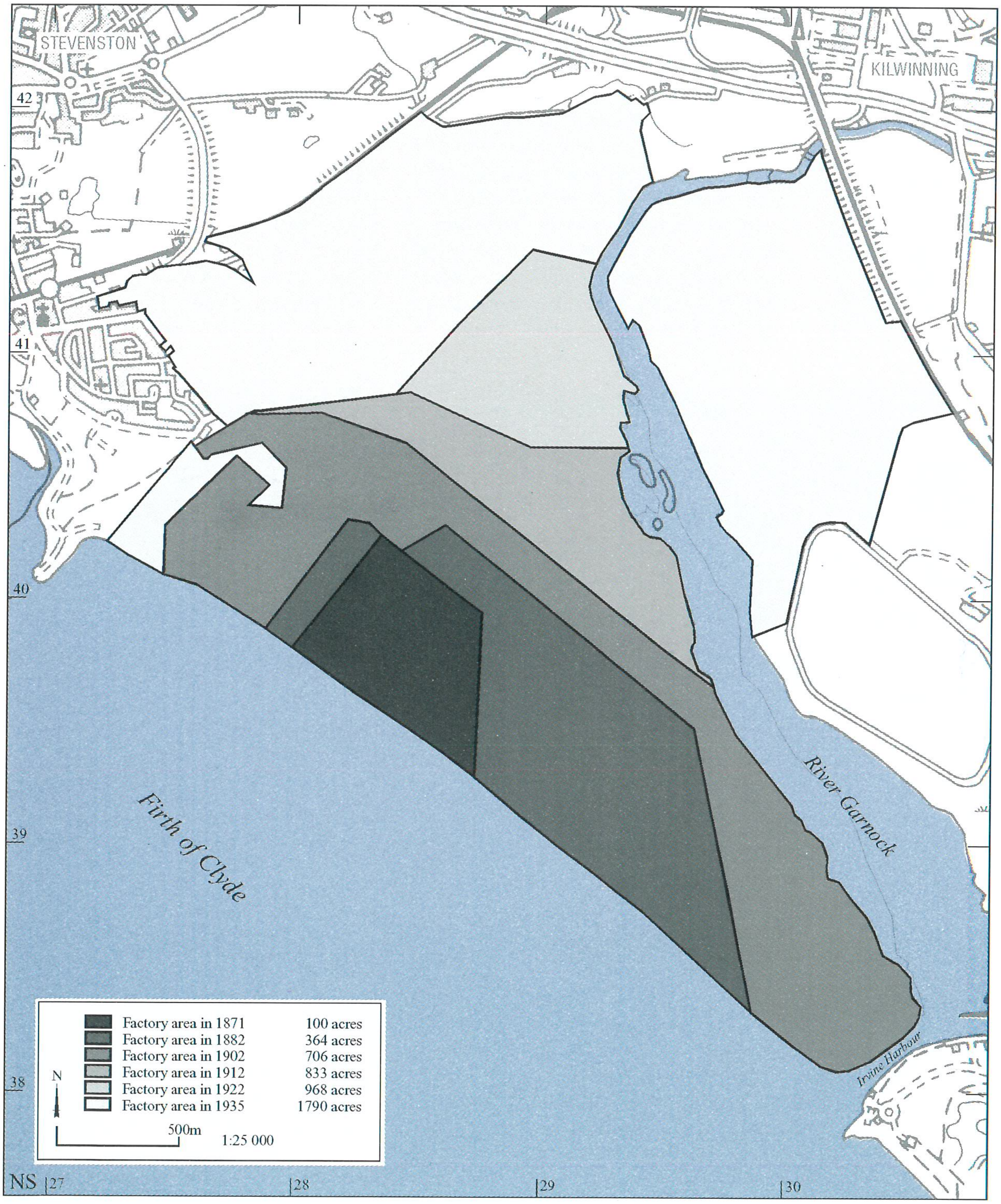
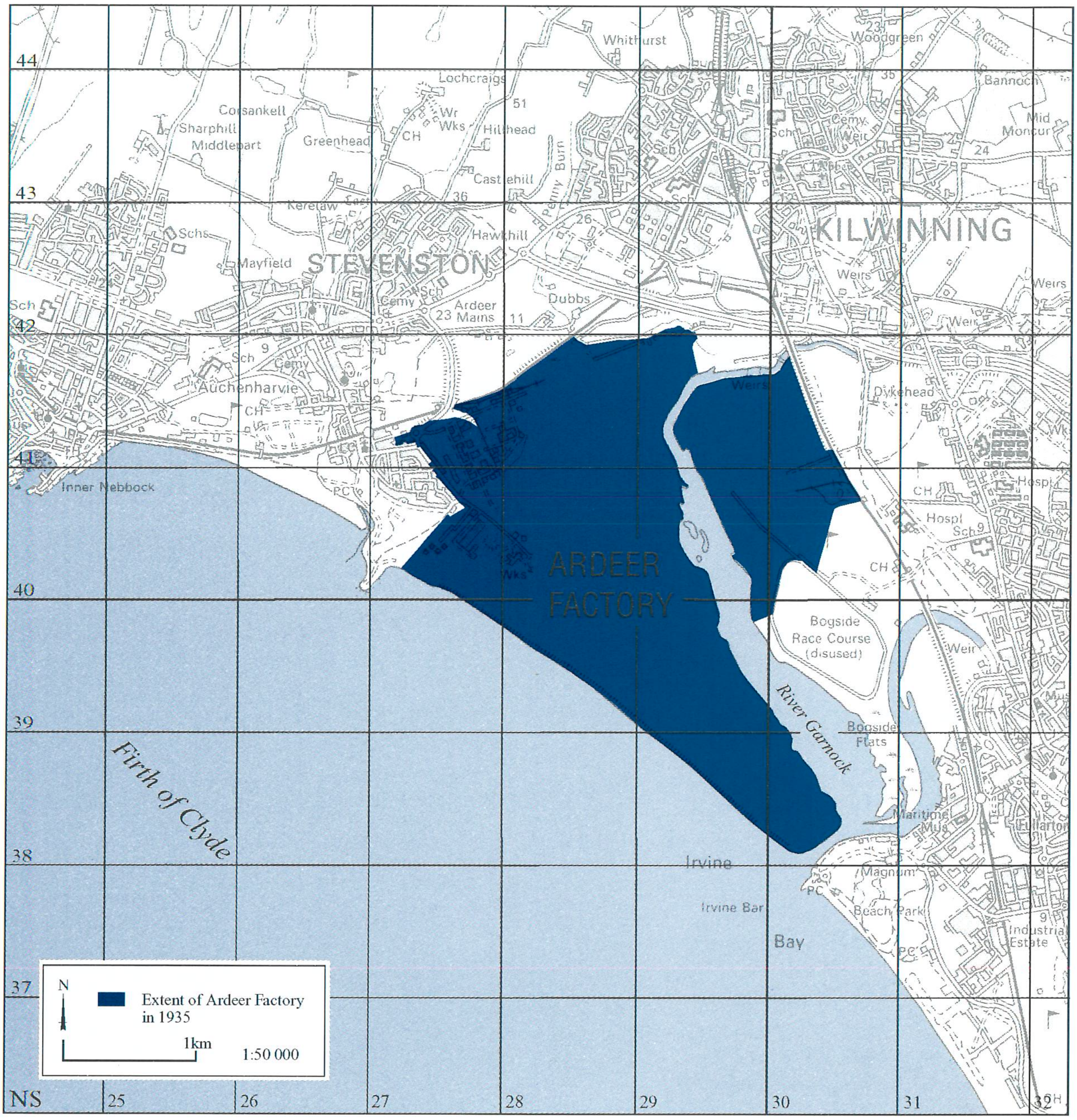


Figure 5: (above) Map showing growth of the Ardeer Factory from 1871 to 1935 (based upon the 1994 Ordnance Survey 1:50,000 Outline Edition 'Landranger' [Sheet 70] Map, with the Permission of The Controller of Her Majesty's Stationery Office, © Crown Copyright, and ICI 1938)

Figure 6: (top right) Location Map showing peninsular in relation to surrounding towns of Saltcoats, Stevenston, Kilwinning and Irvine (based upon the 1994 Ordnance Survey 1:50,000 Outline Edition 'Landranger' [Sheet 70] Map, with the Permission of The Controller of Her Majesty's Stationery Office, © Crown Copyright)



are always raging and foaming. Now you will have some idea of the place where I am living. Without work, the place would be intolerable'.[20]

In reality, Ardeer was the perfect location for Nobel's factory. Apart from being an easily accessible situation for shipping, and being conveniently close to the thriving industrial core of central Scotland, it was relatively isolated, being situated on a natural peninsular with the Firth of Clyde on its west side, the

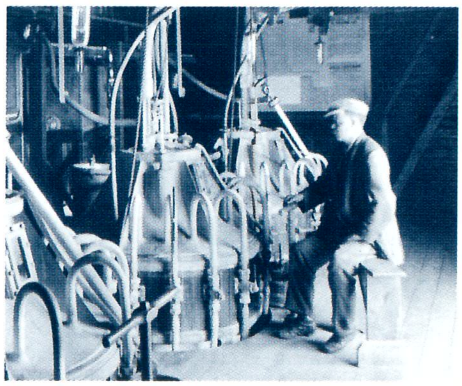
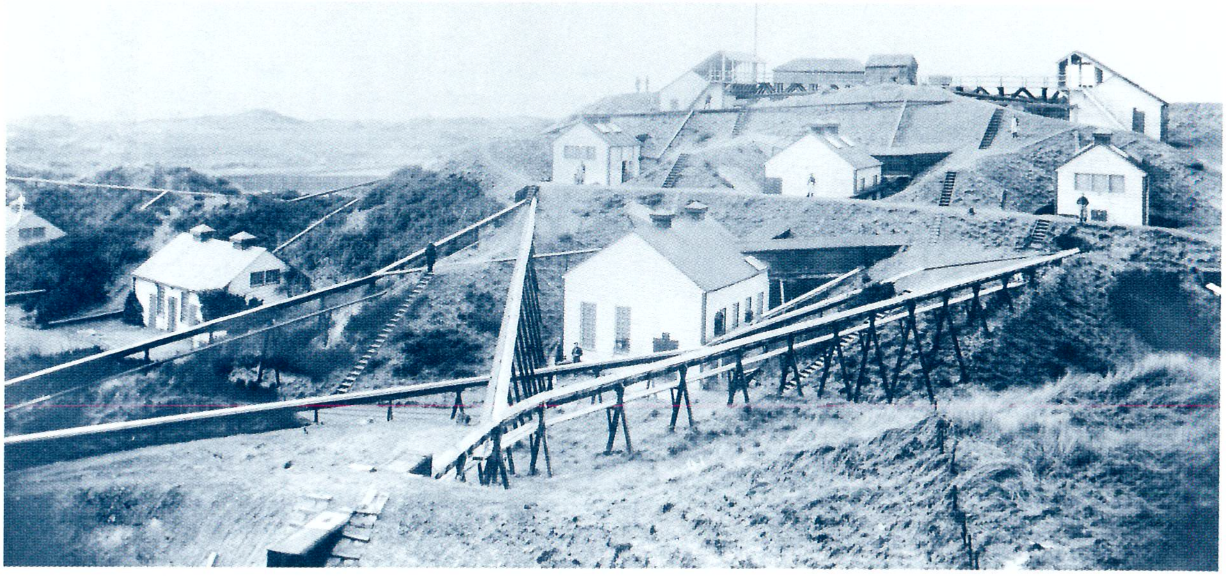


Plate 12: (right) Detailed view of Nitro-glycerine nitrators, circa 1925. This view shows an arrangement of three nitrators (ICI Explosives, C47088)



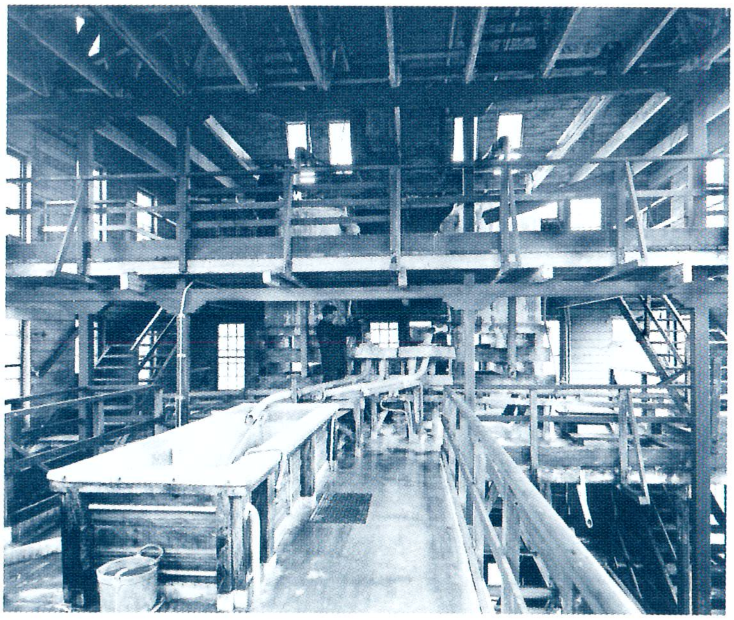


Plate 13: (above) Interior view of Nitro-glycerine nitrating house, showing nitrators in background (above), and separators in foreground, circa 1925 (ICI Explosives, C47092)

River Garnock to the east, and the mouth of the River Irvine to the south [Figure 6 on page 25]. Perhaps more important still was the suitability of the land itself, the sandy surface providing a perfect material for the raising of embankments and mounds to isolate the danger zones within the factory, which themselves could be separated by wide stretches of sterile land. In the event of an accident, therefore, the layout was intended to render each explosives production area sufficiently isolated to prevent a chain reaction of explosions, reduce the disruption to production in unaffected areas, minimise potential harm to the workforce, and comply with strict government regulations.[21] A further advantage of mounded buildings was that the regulations allowed them to be located closer together than unprotected buildings, thereby allowing for a more compact layout of parts of site.

At the heart of the factory was the production of Nitro-glycerine. This was achieved by production units known as 'Nitro-glycerine Hills', the arrangement of which was designed to take advantage of gravity, preventing any need for pumping once the nitration process had begun [Plate 11]. The Nitro-glycerine mixing or nitrating house [Plates 12 and 13] was therefore situated at the top of the 'hill', the Nitro-glycerine and waste acids subsequently flowing down a network of lead-lined gutters and pipes, and through sequences of wash, separation and labyrinth houses, accumulating in a final wash and storage house, now referred to as a 'C' House [Plate 14]. Meanwhile, the last vestiges of Nitro-glycerine were removed from waste acids in a recovery plant [Plate 15], the acid being recycled. Nitro-glycerine was subsequently dispatched from the hill's 'C House' by special bogey (sometimes referred to as 'The Angel') to the mixing and cartridging houses [Plates 16 and 17 on pages 28 & 29] where it was blended with the other ingredients and packaged to produce different types of high explosives.

Plate 11: (left)
View of first Nitro-glycerine Hill, circa 1880. Nitro-glycerine hills utilise gravity, the nitrator houses being situated at the top of the hill, the nitro-glycerine and waste acids subsequently flowing down hill via lead-lined conduits through sequences of separators, wash houses and labyrinths before being dispatched for mixing into explosives
(ICI Explosives, C62971)

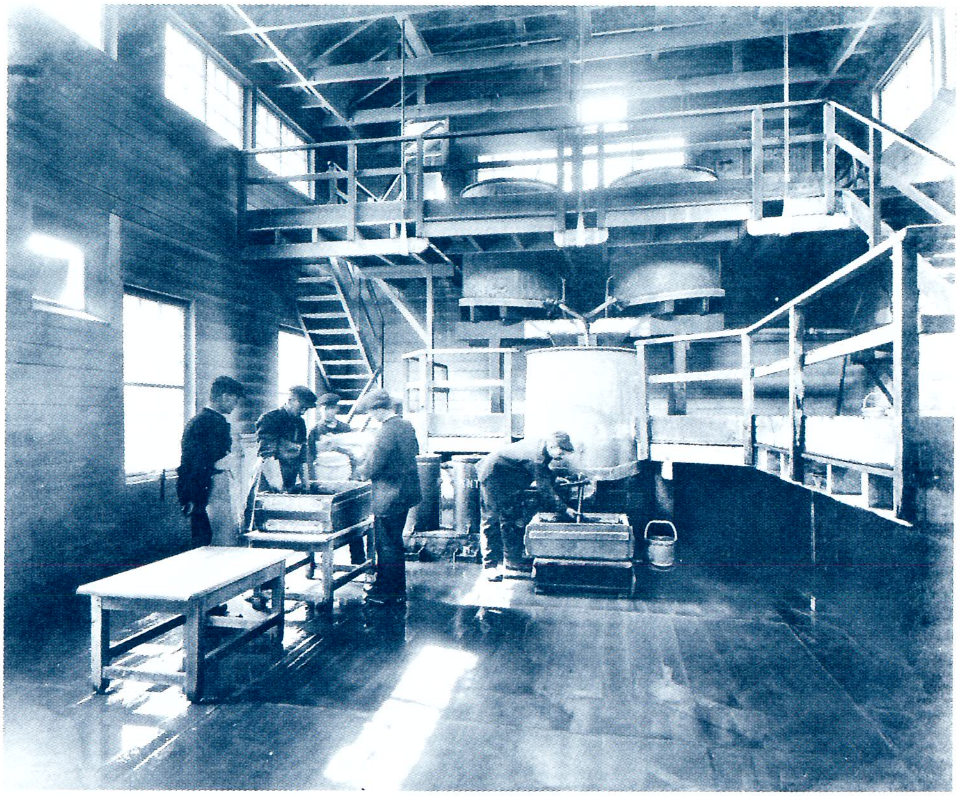


Plate 14: Interior view of Nitro-glycerine 'C' House in which the nitro-glycerine is stored prior to dispatch to the mixing departments, circa 1925 (ICI Explosives, C65504)

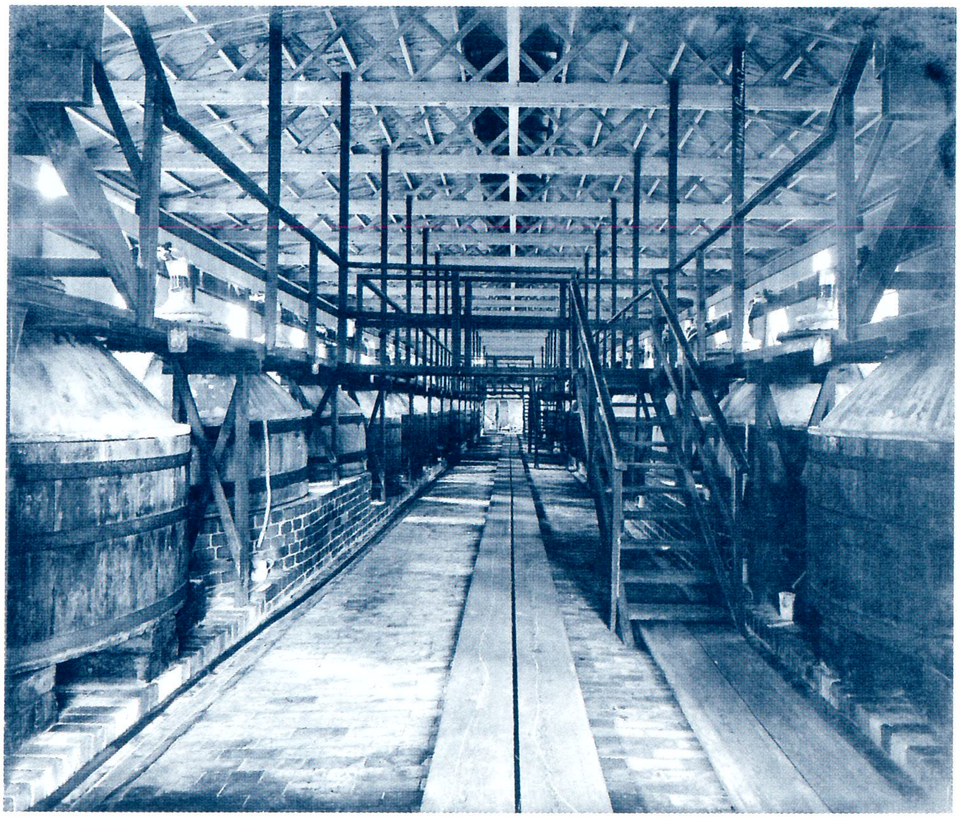


Plate 15: Interior view of plant recovering Nitro-glycerine from refuse acid, circa 1925
(ICI Explosives, C65505)

Plate 16: Detailed view inside a Dynamite Cartridging Hut, circa 1925, showing an original Dynamite cartridging machine in use (ICI Explosives, C65509)

The first Nitro-glycerine hill, Dynamite plant, nitric acid unit and laboratory (converted to the works manager's house in 1879) were all contained in the original 100 acres of the landward section of the site. The addition of a second Hill and a Nitro-cotton plant in 1891, and the construction of a third Hill in 1882 resulted in the expansion of the site to just over half a square mile. Between 1890 and 1896, a further three Nitro-glycerine Hills were established, and by 1902, the factory had grown to cover about one square mile, with

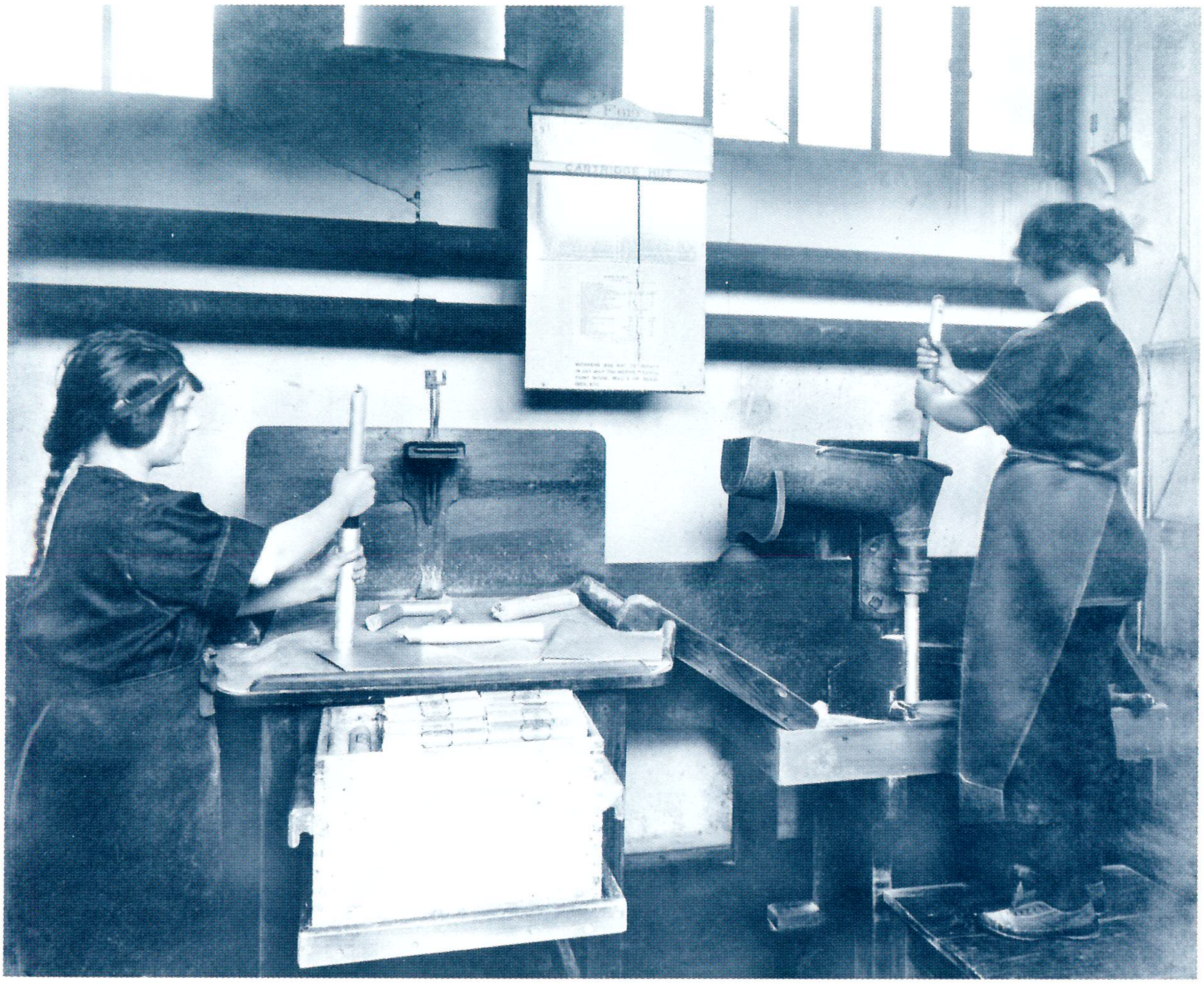


Plate 17: Detailed view inside Powder Explosives Hand-Cartridging Hut, circa 1925 (ICI Explosives, C65510)

450 separate structures within which 1,200 people were employed.[22] The growth had been assisted by the expansion in export trade, itself greatly aided by connections to the main-line railway network, and in particular by the construction in 1902 of direct quayside loading facilities. In addition, the range of explosives being manufactured at Ardeer expanded with the addition of Lyddite (Picric Acid) and TNT. With the onset of the First World War, the neighbouring Misk Farm, comprising 120 acres of land and situated directly to the north of the existing factory, was acquired in 1914 to produce Cordite for the war effort. It was mothballed after the war, its Nitro-glycerine Hills subsequently being used to supply the Misk Gelatines plant. [Figure 7, page 30].

In order to produce Nitro-glycerine and other nitro-group explosives, large quantities of nitric and sulphuric acids were required, as well as other chemical ingredients such as glycerine and glycol. One of the great features of the Ardeer factory was the reliable quality of its products. Quality control was achieved primarily because of the way in which it was rapidly developed into a vertically integrated factory, relying upon external suppliers only for the basic raw materials such as coal, sulphur (initially in the form of cuprous iron pyrites from Spain), and nitrates. In addition to glycerine refining capacity (Plates 18 and 19, page 31), there was impressive nitric acid (Plates 20 and 22, page 32) and supphuric acid (Plate 21) capacity built on site, the factory also selling acid to external customers on occasion. Indeed, in 1907, Nobels claimed that the Ardeer Acids department was itself the largest acids factory in the world.

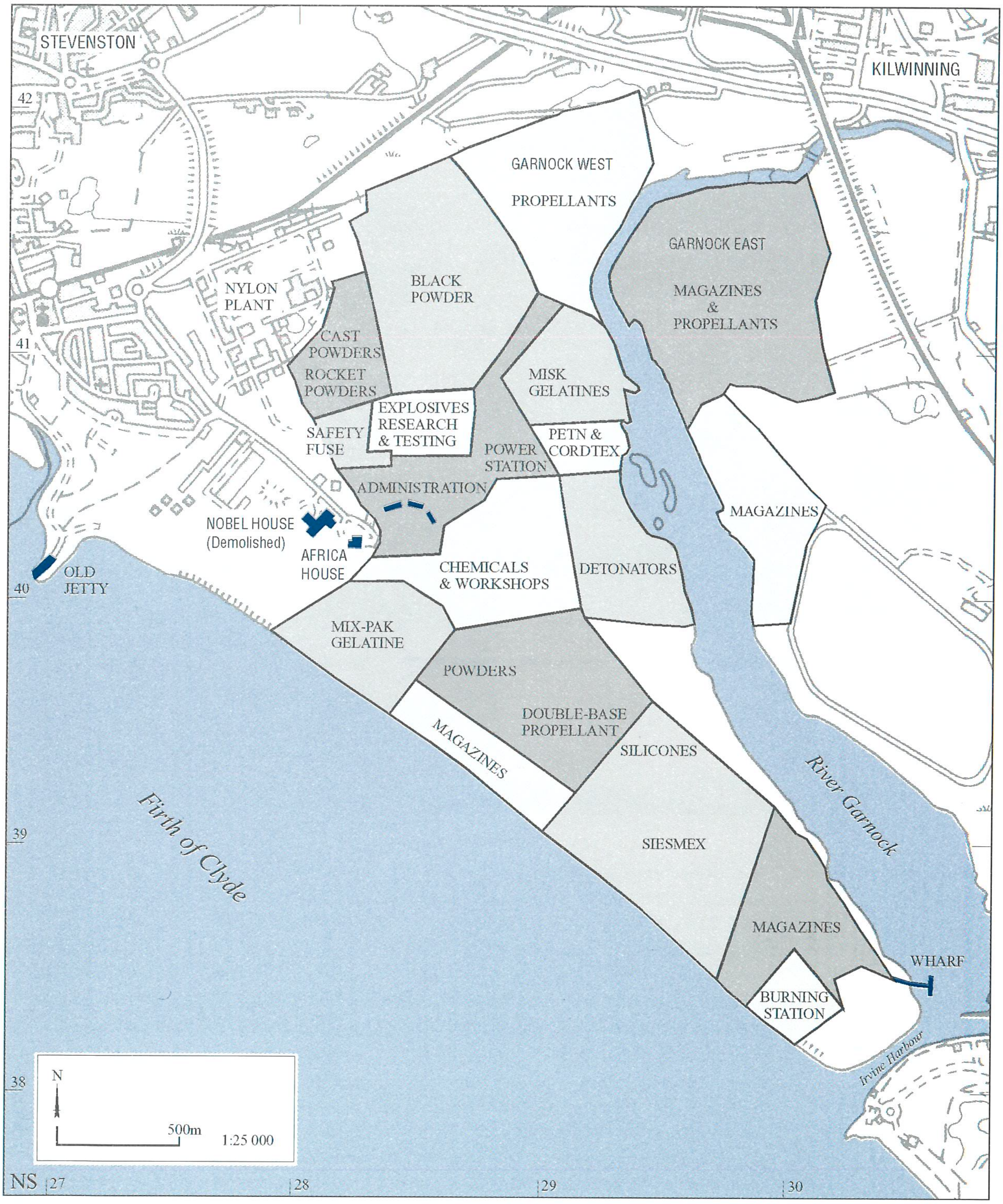
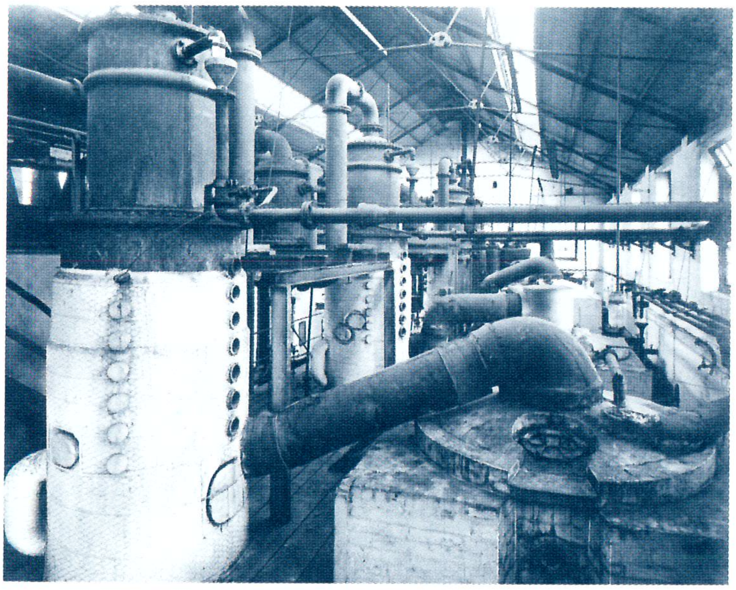


Figure 7: Historical Map showing generalised layout of factory (based upon the 1994 Ordnance Survey 1:50,000 Outline Edition 'Landranger' [Sheet 70] Map, with the Permission of The Controller of Her Majesty's Stationery Office, © Crown Copyright)

Plate 18: *Interior view of Glycerine Refinery distillation plant, circa 1925 (ICI Explosives, C62995)*

Plate 19: *Exterior view of Glycerine Refinery, which refined large quantities of glycerine for nitration to produce nitro-glycerine, circa 1925 (ICI Explosives, C66034)*



Equally important were the supporting departments responsible not only for the repair and maintenance of the factory, but also for the production of the wide variety of materials essential to day-to-day operations. In addition to engineering-based workshops manufacturing, repairing and maintaining mechanical items of all varieties, there were plumbers, electricians, laundries, and sailmakers. One of the busiest activities centred on the extensive joiners' shops and carpentry departments, whose major task was the construction and maintenance of the wooden huts, sheds and Nitro-glycerine gutters associated with the most hazardous processes, wood offering the least resistance and minimising damage caused by accidental explosions [Plate 23, page 33]. In 1907, Nobel's Book of High Explosives describing the Ardeer factory explained that Government regulations require that buildings '...must be built entirely of light wood with a light roof so that its debris under force of an explosion is attended with the least danger to those working in surrounding buildings. The walls must be papered or varnished to enable them to be easily and frequently cleaned of any possible accumulations of the dust of the various

Plate 20: Interior view of Nitric Acid plant, circa 1925. Nitration processes require large quantities of concentrated nitric acid which were supplied on site at Ardeer by an Acids Department said in 1907 to be the largest in the world (ICI Explosives, C62989)

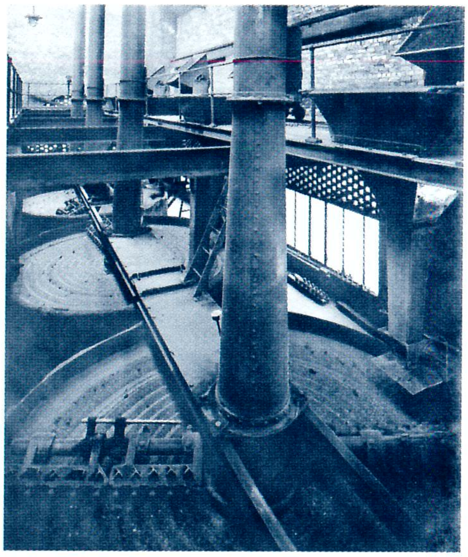


Plate 21:(above) Interior view of Tentelew Sulphuric Acid plant units 3 and 4, showing tops of Hereshoff Kilns, circa 1925. Concentrated sulphuric acid was a vital component in the nitration process, absorbing unwanted water (ICI Explosives, C62985)

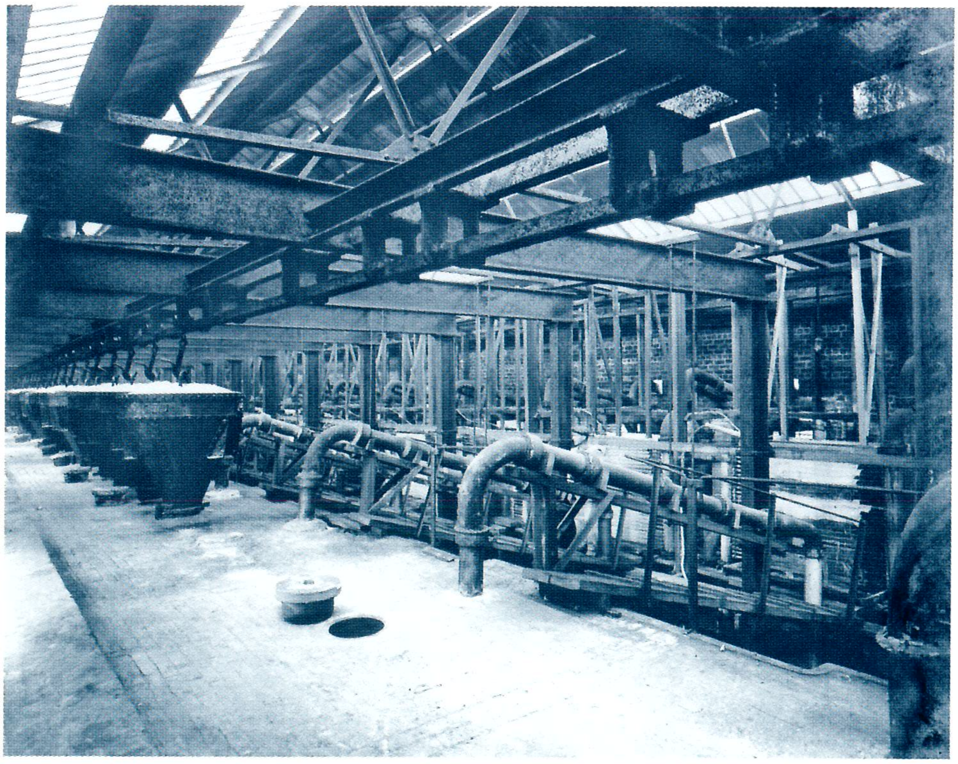


Plate 22: Interior view of Nitric Acid plant showing top of retorts, with nitrate of soda hoppers and Harts Condensers, circa 1925. Nitration processes are central to the ingredients of most explosives, and require large quantities of nitric acid (ICI Explosives, C 62990)

explosive substances.'[23] Each building was also required to have a light blast panel (to release accidental blast effect within the building) faced with a blast wall usually built either of brick or concrete, and designed to deflect any blast in a direction in which least damage was likely.

Other significant departments included box and case making for the packaging of explosives [Plate 24 and Figure 8], and printing for cartridges and instruction leaflets. Process steam was provided by an impressive central boiler house [Plate 25, page 34], and electricity and compressed air by the factory's own power station [Plate 26, page 35]. Narrow

Plate 23: View of original Dynamite cartridging huts situated beneath nitro-glycerine hill (left), illustrating the wooden construction and layout of the buildings, circa 1880, (ICI Explosives, C62976)

Plate 24:(below) Interior view of Box Factory, showing nailing and trimming machines, circa 1925 (ICI Explosives, C65560)

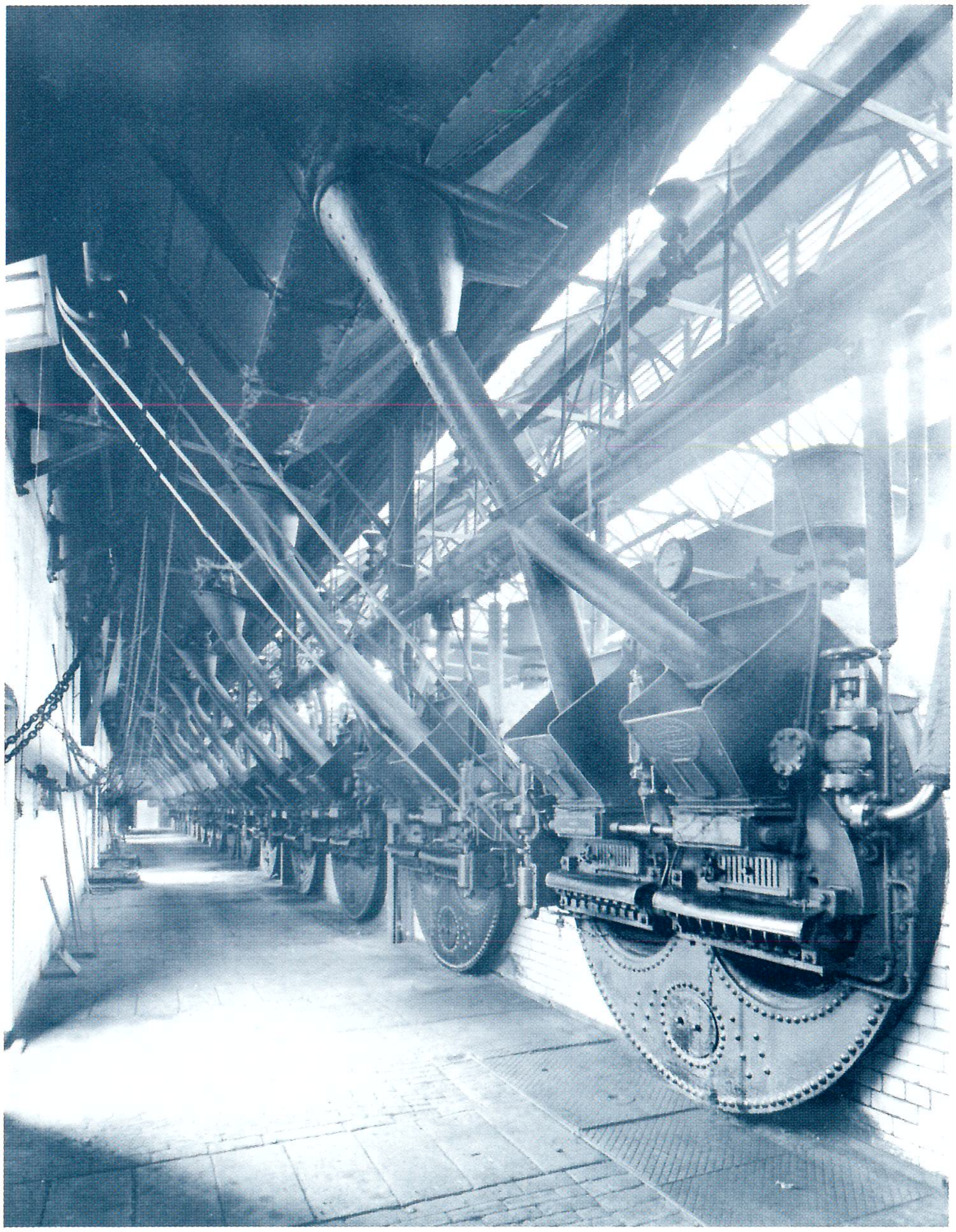


Plate 25: Interior view showing the coal-fired Lancashire boilers in the Central Boiler Station, circa 1925 (ICI Explosives, C66045)

gauge railways were built to connect most parts of the site, which were also linked to the national railway network by the factory's own sidings and marshalling yards [Plates 27 and 28]. However, a large proportion of the factory's output was exported directly via its own jetty at the south-east end of the peninsula [Plate 29, page 36]. Meanwhile a network of metalled roads also evolved, many with evocative names such as Propulsives Road, Burma Road, New Hill Road, and Blackpowder Road, and in combination with covered wooden walkways, 'clean areas' and

Figure 8: Illustration of wooden cases for Nobel's Explosives 1907, (C65818)

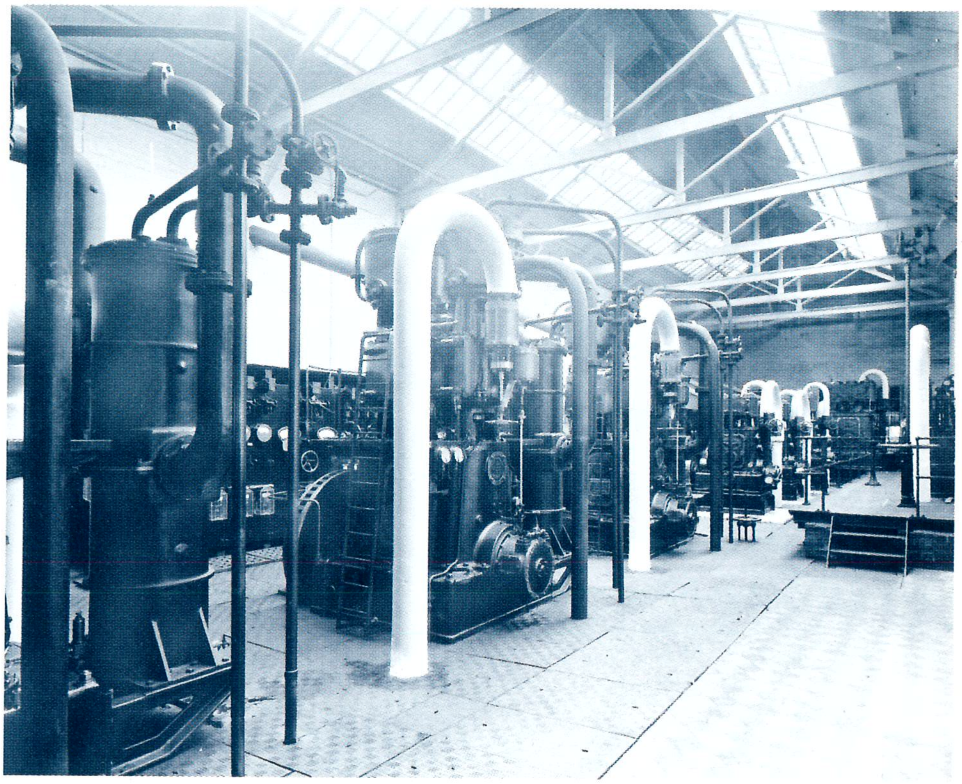
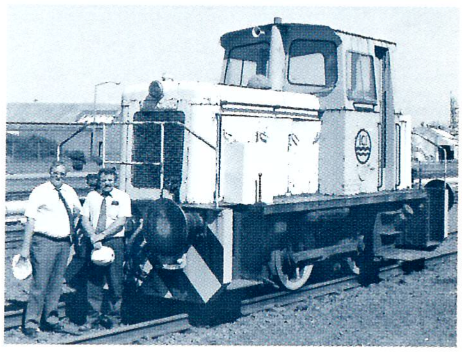


Plate 26: Interior view of Power Station, showing air compressors and high-speed engines, circa 1925 (ICI, C66036)

Plate 27: View of railway train of explosives leaving the factory, circa 1925 (ICI Explosives, C65566)

Plate 28: View of typical Ardeer standard-gauge diesel locomotive, made in 1968 by Andrew Barclay of Kilmarnock, with Messrs. Joe Herring and Jim Smith of ICI Explosives, 1995 (RCAHMS, C60169)

wooden gangways and street lamps, created the atmosphere of a bustling town. Indeed, even by today's standards, the factory's infrastructure was, and is, quite exceptional. As the factory expanded and diversified, and the number of explosives and non-explosives products grew, so new production areas appeared, many of these changes coinciding with major expansions of the site as a whole. Initially, the most important new areas related to explosives such as Nitro-cotton [Plates 30,



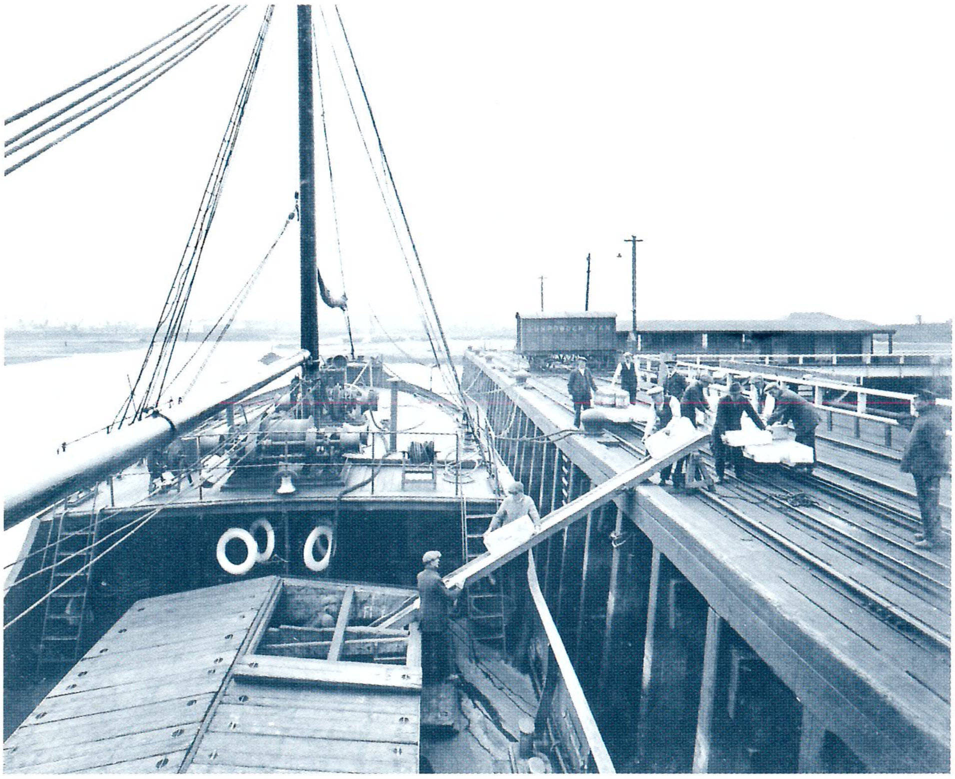


Plate 29: View of explosives being loaded into ship at the Factory Wharf, circa 1925. The wharf was built in 1902 (ICI Explosives, C65565).

Plate 30: Interior view of Nitro-cotton kiering and teazing house, circa 1925. Nitro-cotton was one of the most important sources of nitro-cellulose, the many applications of which include the mixing with nitro-glycerine to produce different types of high explosives and propellants (ICI Explosives, C66051)

31 and 32] and Blasting Gelatine [Plate 33, page 38], accompanied by propellants including Nobel's Ballistite [Plates 34, page 38], and subsequently Cordite [Plate 35 and 36, page 39]. In later years, the capacity of other Nobels' factories throughout the United Kingdom was consolidated at Ardeer. In particular, many blackpowder works were closed down in the 1930s, some of their machinery and personnel being re-located at

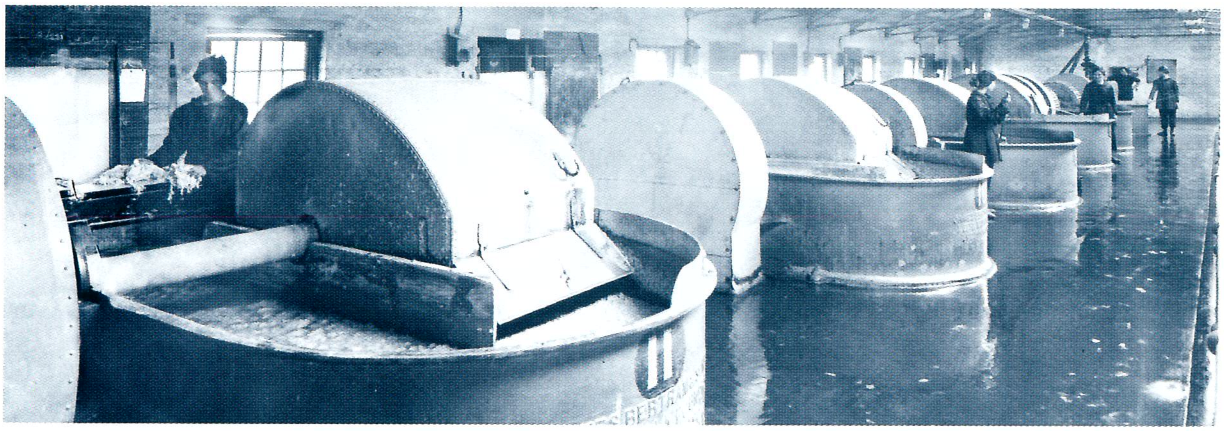


Plate 31: Interior view of Nitro-cotton Pulping and Finishing House, showing pulpers made by James Bertram of Leith, circa 1925 (ICI Explosives, C66053)

Plate 32: Interior view of Nitro-cotton pulping and finishing house showing potchers and pulpers, circa 1925 (ICI Explosives, C65520)

Ardeer [Plate 37 and 38, page 40]. Safety fuse production was also established in the factory [Plate 39 and Figures 9 and 10, pages 41, 42], and large-scale detonator manufacture eventually replaced the Westquarter Factory near Falkirk [Plates 40, 41, 42, 43, 44 and 45, on pages 42 and 43]

In the period after the Second World War, dramatic changes in explosives manufacturing technology took place, with the rapid development of mechanised and remotely controlled production methods adapted and pioneered by Ardeer engineers to the specific requirements of the explosives industry. Of these, some of the most important included the mechanisation of the manufacture of gelatines in the 1950s with the installation of multi-cartridging machines and packing houses in the Misk unit; the extension of the mechanisation programme in the 1960s to install full remote-control in the unique Mix-Pak unit installed on the site of the old Dynamite powders unit, involving the remotely

Plate 33: (above top) Interior view of Gelatines explosives mixing house, circa 1925. The machinery on each side of the building includes McRoberts Mixers (ICI Explosives, C47080)

Plate 34: (above bottom) Interior view in Propulsives Department, showing Ballistite packing house, including gauging and examining finished cartridges, circa 1895 (ICI Explosives, C62959)

Plate 35: (above) Interior view in Propulsives Department, showing Cordite paste mixing house, circa 1925 (ICI Explosives, C65546)

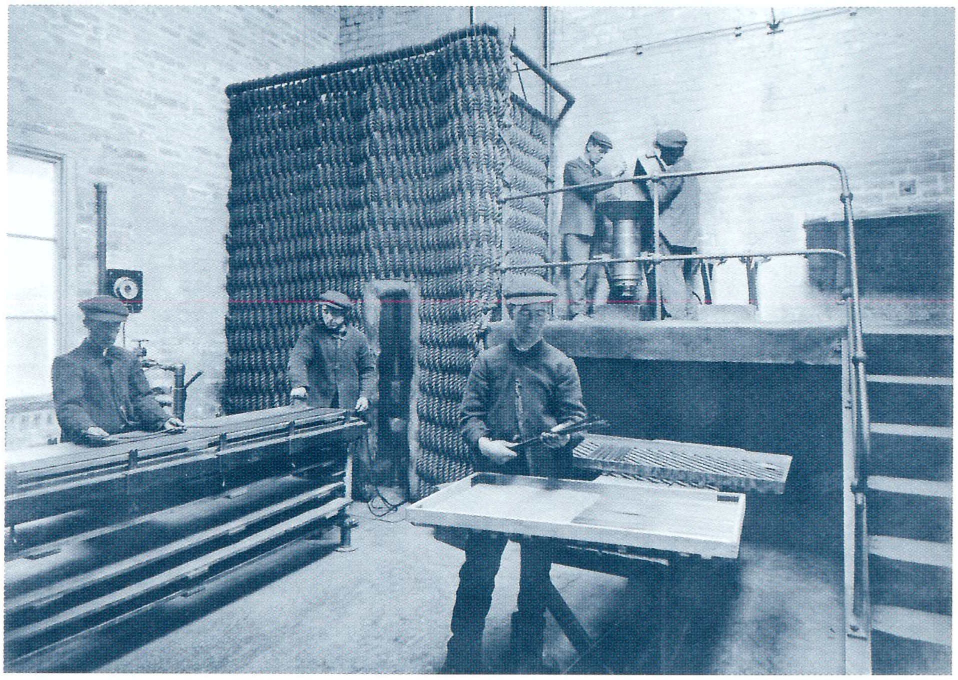


Plate 36: (right) Interior view in Propulsives Department, showing Ordnance Cordite Press House, circa 1925, (ICI Explosives, C65548)

Plate 37: General view of GZ4, a range of Blackpowder incorporating mills, 1991. These mills were the last surviving range of blackpowder mills in Britain (RCAHMS, B48307)

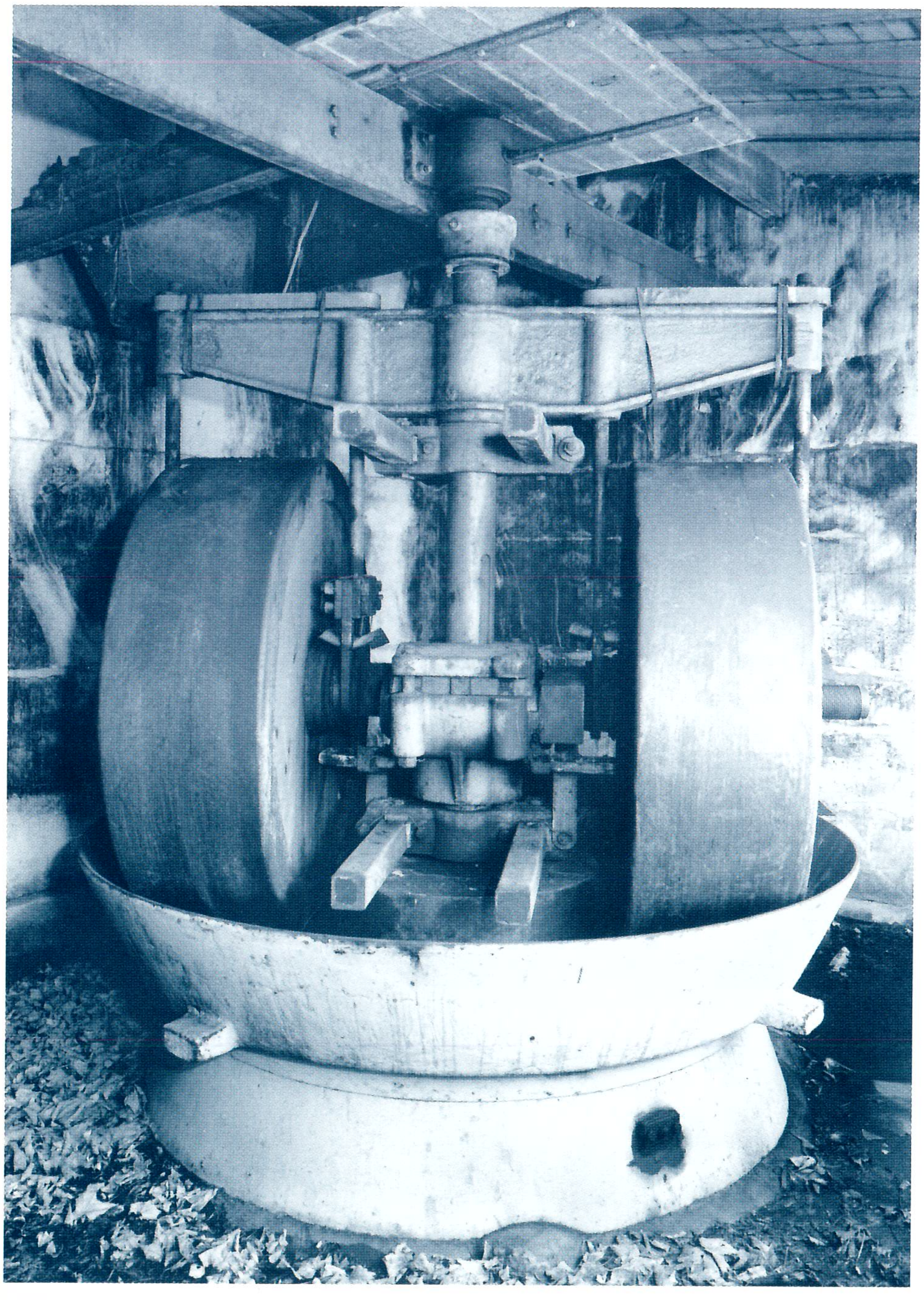


Plate 38: Detailed view in GZ4 showing disused, electrically-driven (from below) blackpowder suspended edge-runner incorporating mill, 1991 (RCAHMS, B48309)

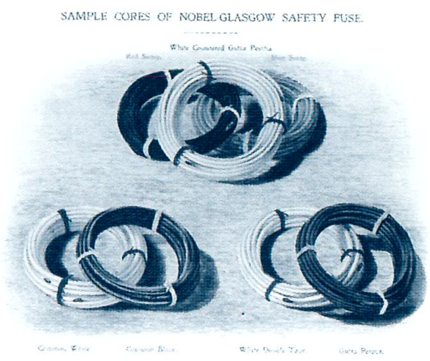


Figure 9: Illustration showing different brands of Safety Fuse (Nobel's Explosives, 1907)

controlled Nitro-glycerine hill being coupled with mixing and cartridging machines; also in the 1960s, the introduction of continuous injector nitration for Nitro-glycerine, which significantly improved safety; from the 1950s onwards, major mechanisation and automation of detonator manufacture, resulting in the world's first fully-automated electric detonator assembly unit.

By the 1970s, these developments had completely transformed the original Liedbeck plant, which was being further changed by the

Plate 39: Interior view showing line of drying wheels in the Safety Fuse finishing department,1990 (RCAHMS, B41113)

Figure 10: Detail of Nobel's 'Union Brand' Safety Fuse label (B39941)

introduction of more conventional chemical manufacturing, and which now included a large nylon intermediates manufacturing plant at the north end of the factory (on the site of Lucknow Colliery, see Plate 2).

It is difficult to describe in simple terms how the Ardeer factory appeared, not only because of the numerous very different operating departments, but also because it was continuously growing and evolving. Apart from the distinctive Nitro-glycerine hills, the wooden huts and sheds, and the typical corrugated sheet-metal-clad defensive mounds (including Chilworth mounds) isolating hazardous process buildings and magazines

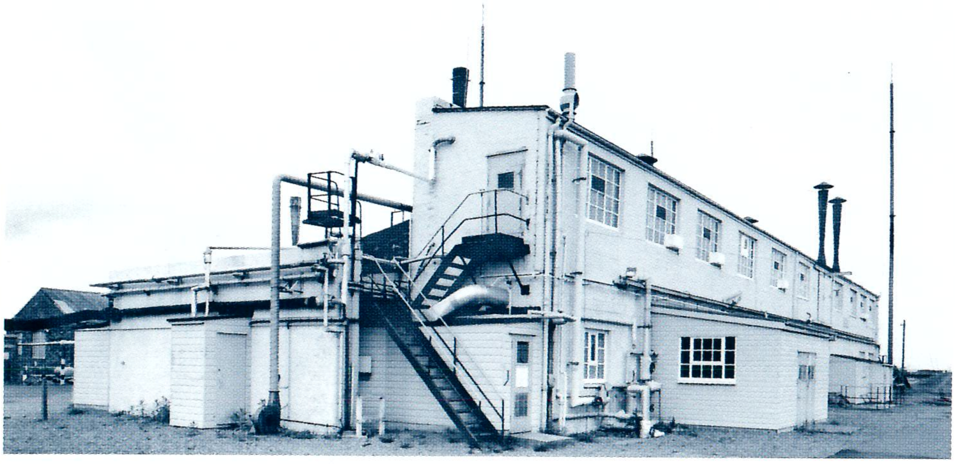


Plate 40: Exterior view of Detonator Department's Chemical Plant, 1995 (RCAHMS, C38900)

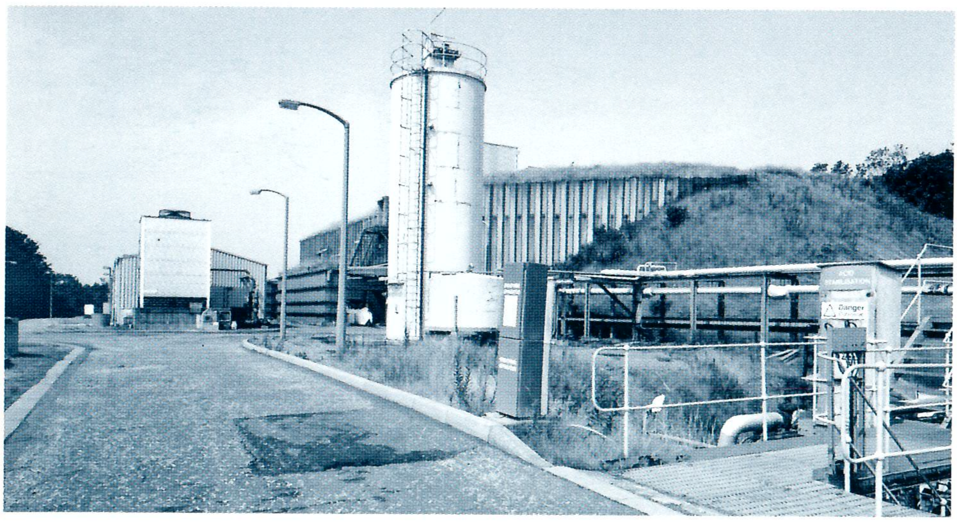


Plate 41. Exterior view of PETN Plant, 1995 (RCAHMS, C60223)

Plate 42: (left) Detail in Detonator Department showing bonding press, with Malcolm Greaves displaying the different elements making up fusehead combs, 1995, (RCAHMS, C60181)

Plate 43: (right) Detail in Detonator Department showing Brenda Cain operating a fusehead dipping frame, 1995 (RCAHMS, C60188)

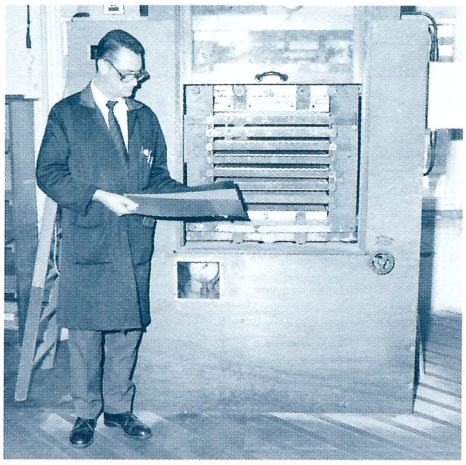


Plate 44: (left) Detail in Detonator Department showing Ann Anderson at Position 3 in Compartment 6 operating a hand-assembly machine for electric detonators, 1995 (RCAHMS, C38931)

Plate 45: (right) Detail in Detonator Department showing Angela Graham hand coiling fusewire into 'Figure of Eight' coils on the hand-coiling bench, 1995 (RCAHMS, C38925)

Plate 46: Blasting Department: view of bogey with finished cases of Gelignite leaving a packing house on the narrow gauge railway, and being taken for storage in a Magazine. The view also illustrates the steel-re-inforced mounds surrounding these and other types of building in the Danger Areas, circa 1925 (ICI Explosives, C65514)

[Plates 46 and 57], there were more substantial mostly brick-built buildings containing nitro-cellulose, propellant, and safety fuse manufacturing processes, as well as large buildings housing workshops and other services and departments such as general offices, research departments and laboratories [Plates 47, 48 and 49]. Other buildings included canteens, a medical centre, stores, and locomotive sheds. Quite a number of the production buildings were also constructed from a core of re-inforced concrete, providing, for example, compartmentalisation within blackpowder incorporating mills and detonator filling departments, and also for some of the later blasting gelatine mixing houses. Indeed, such heavily re-inforced construction became an essential component at the heart of the new remote-controlled and automatic explosives manufacturing units developed after World War Two.

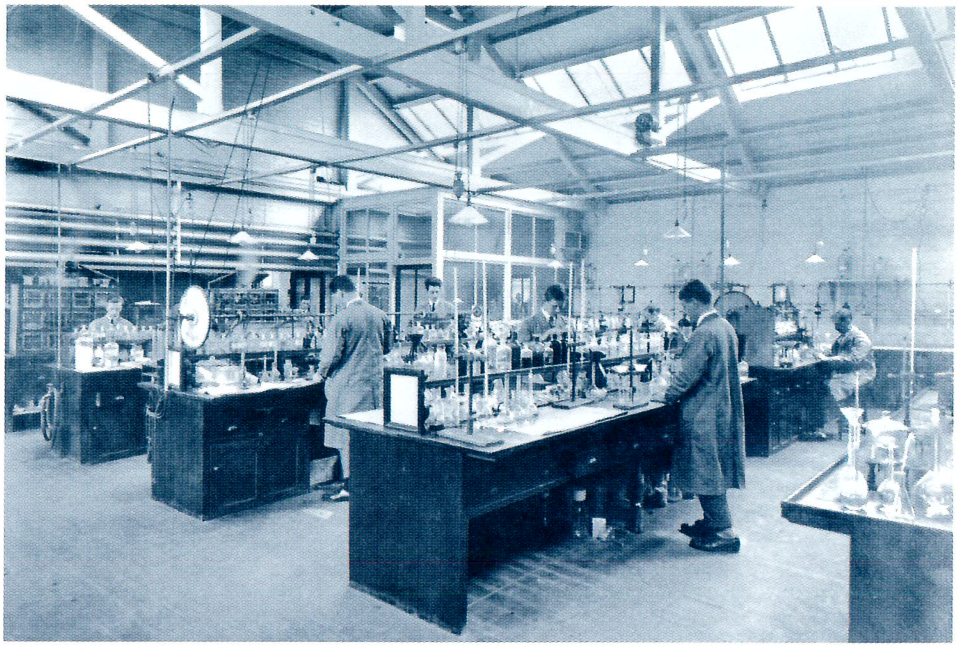
Plate 47: Exterior view of General Offices, circa 1925 (ICI Explosives, C66040).

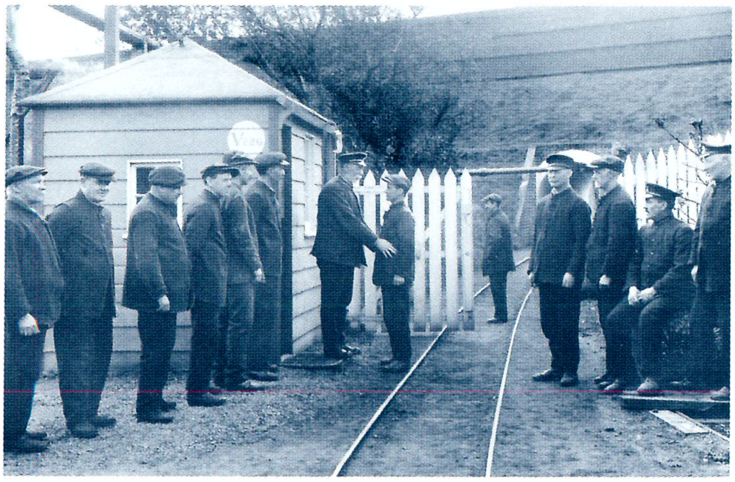
Plate 48: View from north west of central range of Offices, Laboratories and Library, incorporating what is now referred to as Nobel House. These buildings date from the formation of ICI in 1926, and were built to house ICI's research centre, comprising the Research Department Headquarters, and including an office for the Research Manager, and associated administrative offices, laboratories, and the library. 1995 (RCAHMS, C38963).

Plate 49: Interior view showing Routine Laboratory, circa 1925 (ICI Explosives, C47089)

Plate 50: View of workers being searched at the entrance to a Danger Area, circa 1925. In the interests of safety, strict rules on contraband were applied (ICI Explosives, C66043)

Plate 51: View of women workers queuing at the searcher's box at the entrance to a Danger Area, circa 1925 (ICI Explosives, C66042)





On a lesser scale, there were a variety of smaller structures, typical examples being the searcher's boxes [Plate 50] at entrances to the 'danger zone' where workers were searched for forbidden contraband such as matches, lighters, ferrous-metal objects, electrical equipment and other potentially dangerous items [Plate 51]. More unusual buildings included boot houses where employees were obliged to change into rubber safety shoes or 'polar boots' before entering 'clean areas' [Plate 52, page 46], some of which were covered with rubberised flooring. Indeed, the many rigorously applied safety regulations included pocketless clothing, and the banning of hair pins and clips in favour of ribbon. In some areas where static electricity was a serious hazard, even nylon clothing was prohibited, and special shoes were mandatory.

To the uninitiated, some of the more extraordinary features of the factory are the very long wooden corridors [Plate 53, page 47] connecting various buildings and departments, particularly within the Detonator Department, and between the Nitro-glycerine hills and Gelatines mixing houses. In these and other areas, features include intrinsically safe electric light fittings, wooden rails to guide bogeys used to carry detonators and explosives

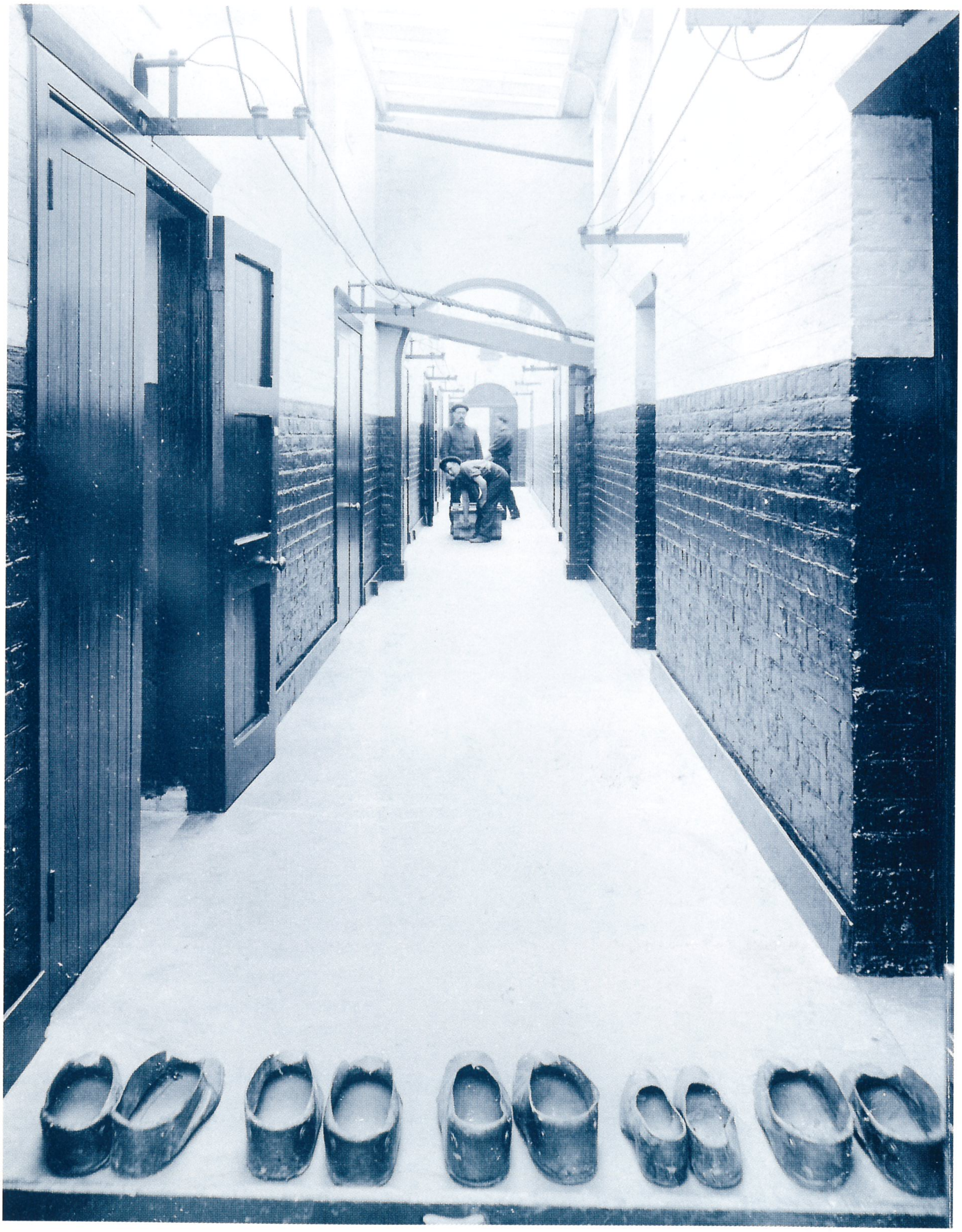


Plate 52: Propulsive Department: interior view showing entrance to a Ballistite Powder House, a 'clean' area requiring the wearing of safety shoes (visible in the foreground, and including 'over-shoes'), circa 1900 (ICI Explosives, C62962)

Plate 53: Interior view along covered walkway No.4 within the Detonator Department, showing a long section of wooden walkway typical of several areas of the factory, 1995. One of the main purposes of these enclosed corridors was to prevent sand from blowing or being carried into production areas. (RCAHMS, C38948)

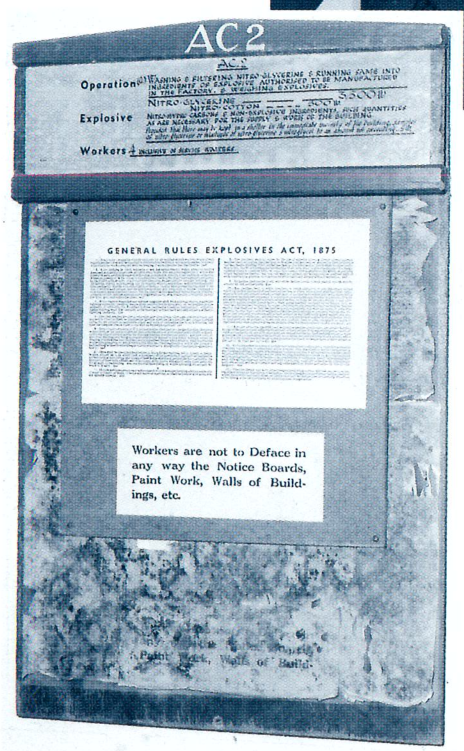


Plate 54: Detail of typical pedimented noticeboard in the 'C' House of Nitro-glycerine Hill No. 2, providing details of the operations, explosives and workers permitted in the building at any one time, 1995 (RCAHMS, C60109)

from one building to the next, and small pedimented wooden notice boards [Plate 54] on the walls of buildings carrying information on the manufacturing methods and explosives licences. Perhaps the greatest impression of all is the emphasis on safety, the arrangement of all spaces having been designed to minimise both the risk and the effects of accidents.

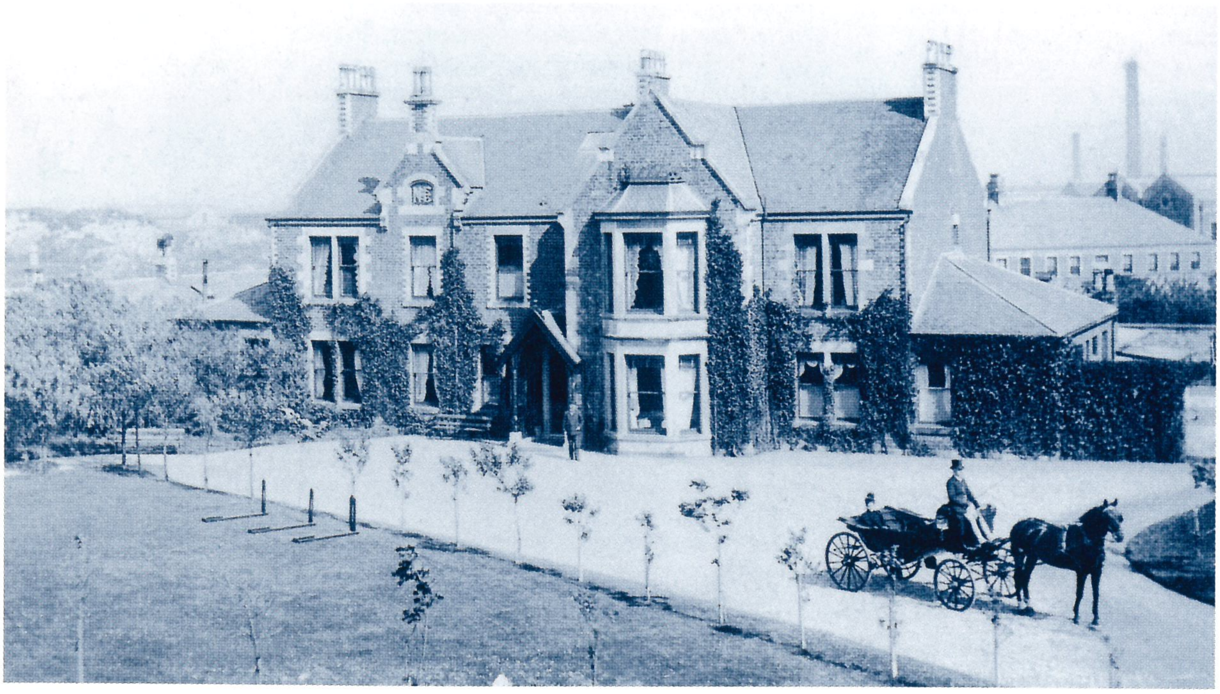


Plate 55: View of the Manager's House in 1902, later to become 'Nobel House' (ICI Explosives, C62973)

The technical revolution that Nobel's detonator and Dynamite triggered was immediate and far-reaching, and the embryonic industries he established had a meteoric rise which engendered intense commercial and corporate rivalry. Nobel's Explosives Company and Ardeer were inevitably caught up in this corporate battlefield.[24]

to set up a Trust Company. In this, Nobel and Reid were in agreement, but in the event, it was decided to set up two trust companies, one in Paris and the other in London. Thomas Reid, together with Charles Tennant, worked towards the implementation in the UK, setting up The Nobel-Dynamite Trust Company in 1886.

Figure 11: Illustration containing portraits of principal managers of the Nobel's Explosives Company Limited, Glasgow, including Harry McGowan (then the Deputy Assistant Manager), and C O Lundholm (Chief Chemist), (Nobel's Explosives 1907, C65820)

The rivalry and competition had reached a climax by 1883, when a major internal power struggle occurred within Nobel's Explosives. The then General Manager, A A Cuthbert, resigned, and Thomas Reid was appointed Chairman. In 1884, he was joined on the board by Charles Tennant, the head of the great Glasgow heavy chemicals firm based at St Rollox. These two strong personalities were to have a profound effect on the emerging situation. Meanwhile, Nobel's other European operations had also prospered, and, with equally strong personalities at the helm, antagonisms developed, Nobel's solution to which was a fusion of all the Nobel Companies in Europe under a single overall control. Thomas Reid is credited with the idea that the best way to handle this situation was

This proved to be a very advanced form of business organisation, the like of which had never previously been seen in London. It was, in effect, a holding company which controlled the disposal of the assets of its members, and had absolute authority over them, even though the members were themselves corporate bodies. The group brought together: Nobels Explosives (Scotland); Four German Union Companies; The Mexican Nobel Company; The Brazilian Nobel Company; The Pacific Nobel Company; The Alliance Explosives Company; and The South Wales Explosives Company. The Trust was an instant success, and continued (with some changes) until the First World War when, in 1915, it was disbanded because of its components' incompatible national interests.

At this time, another driving personality, Harry McGowan, had emerged to take up a powerful position within the company. McGowan, a Scot of Glaswegian origin, joined Nobels in 1894 at the age of fifteen, reputedly as a tea-boy. By 1909, he was Assistant General Manager [Figure 11], and was in command by the time the Trust Company was disbanded in 1915, directing affairs from Glasgow. Like Nobel, McGowan had a shrewd grasp of the financial realities, and a candour which occasionally shocked both his directors and shareholders.

By 1915, McGowan had very ambitious views concerning the future of Nobel's Explosives, in the context of the chemical industry in Great Britain as a whole, and the international chemical industry. He therefore initiated a series of mergers which brought together into one group all the major explosives, propellant, blackpowder, safety fuse and shotshell companies in the UK, along with Nobel holdings in Canada, South Africa and Australia. The new group was initially named 'Explosives Trades Limited', and in December 1920 was re-named Nobel Industries Limited. At the head of this merged entity was Sir Harry McGowan, KBE, later to become Lord McGowan. No-one had ever before held a position in the British chemical industry quite comparable to this.

In the post-war recovery period, the German chemical industry became a powerful entity in Europe, and with the formation of I G Farben Industrie, was emerging as a dominant force. McGowan's counterplan involved the formation of a British equivalent to I G Farben, his rationale being that unless British industry consolidated itself in bigger units, the German company would eventually swallow it up. By 1926, Nobel Industries Limited consisted of 36 subsidiary and 16 associated companies throughout the world, of which the principal components were: Nobel's Explosives Limited; African Explosives & Industries Limited; Canadian Explosives Limited; Czechoslovakia Explosives Limited; Romania Explosives Company Limited; Compania Sud-America de Explosivos; Nobel Bickford A G; Eley Brothers Limited; Kynoch Limited (Witton); Kynoch Arklow (Wicklow); Lightening Fasteners; Nobel Chemical Finishes (Belco, later Paints Division); and British Leather Manufacturing Co Ltd.

McGowan's strategy was based on bringing the related and inter-dependent industries of Soda Ash, Alkalis, Acids, Ammonia, Nitrate, Dyes and Explosives together as a single entity on the grounds that, when combined, they would be in a much more powerful position to compete against the German I G Farben Industrie. The specific companies that he targeted for inclusion with the new conglomerate were Brunner Mond, British Alkali and British Dyestuffs.

The logic behind the strategy was that Nobel's had the financial resources, but lacked the diversifying projects. Brunner Mond, on the other hand, had large chemical manufacturing establishments at Billingham and elsewhere, but lacked the capital, and were in the process of seeking some kind of financial alliance with I G Farben. By August 1926, Brunner Mond had already drafted the basis of such an agreement, so McGowan reacted rapidly by intercepting Mond during a return trip from the USA on board the Cunard liner 'Aquitania'. The main conclusions of the resulting McGowan-Mond agreement were drawn up on four sheets of Cunard Line writing paper, and covered essentially every item of importance needed for the formation of a new chemical giant, Imperial Chemical Industries Limited.

The four companies publicly announced their intention to merge on 21 October 1926, and Imperial Chemical Industries was fully operational by 1 January 1927, with McGowan as President, and from 1930 to 1950 as Chairman. He subsequently handed over chairmanship to John Rodgers, another Ayrshire Nobel man, in 1951 after 61 years of service in the company. In these and subsequent years, the roots provided by Nobel's Explosives have proved to be a crucial part of the success of ICI, and is perhaps best symbolised by the evolution of the famous ICI roundel from the Nobel logo into its current form [Figure 12].

Whilst most would claim that Alfred Nobel was the grandfather of ICI, Harry McGowan was undoubtedly the father. Together, they would have made an impressive team. Although there is no record of the two ever having met, the imagination almost demands a scene in which the fifteen-year-old McGowan serves tea to Alfred Nobel, who returns the milk and sugar in an unknowing, symbolic gesture of hand-over.

Figure 12: The evolution of the ICI roundel from Nobel through to today (with permission of ICI)

Plate 56: View of dome-ended former egg-end boilers, used to store glycerine and glycol at the foot of Nitro-glycerine Hill No.2, 1995 (RCAHMS, C60076)

Ardil
An artificial wool fibre spun from vegetable protein obtained from groundnuts. This research was conducted as part of an ill-fated government scheme to develop groundnuts as part of an East African economic development programme.[25]

Ballistite
The fourth of Alfred Nobel's inventions. A **double-base** smokeless **propellant** based on an extension of **blasting gelatine** technology, but consisting of equal proportions of **Nitro-glycerine** and **Nitro-cotton**, de-sensitised with camphor. A high-performance propellant which produced very little smoke.

Benzyl Cellulose
Originally developed as a facing for gramophone records in the late 1920s, it was quite extensively used as a cement laminating safety glass, and as a thermoplastic base for certain moulding powders. Today it has been superseded by polyvinyl compounds.

Blackpowder
The first explosive, reputedly invented by the Chinese over 3,000 years ago. It consists of a mixture of fuel (charcoal) and solid oxygen (in the form of **Nitrate**), which will normally explode when confined. Its principal uses are in artillery, **Fuses, Safety Fuse** and fireworks. A **Deflagrating** or **Low Explosive.**

Blasting Gelatine
Invented by Alfred Nobel, the first truly waterproof high explosive, and the most powerful commercial explosive available today. It consists of **Nitro-glycerine** gelatinised with a small quantity of **Nitro-cotton**. This yields a rubbery material which can be extruded and which can withstand considerable periods of immersion in water and still perform perfectly. **Blasting Gelatine** is still in use today.

Blasting Oil
A term for **Nitro-glycerine**, which, despite its dangerous nature, was used as a blasting explosive prior to the invention of safer **High Explosives**.

Brisance
The shattering effect of an explosive. The combination of power and velocity. The higher the power and the higher the **Velocity of Detonation**, the greater the **Brisance** and shattering effect. High-brisant explosives are required for blasting hard rock such as in hydro-electric scheme tunnels, whereas low-brisant explosives are required for blasting monumental stone where a more heaving than shattering effect is required.

Cellofas
A cellulose ether with a wide use as an adhesive and thickening agent, and as an assistant to detergents, having the peculiar property of holding particles of dirt in suspension, leading to more potent detergents. Another very significant application is its use in oil well drilling muds, sealing cracks in the wall of the drill hole and preventing the escape of the mud.

Chilworth Mound
A steep re-inforced protective earth or sand-filled mound, usually clad in corrugated sheet iron, situated around buildings housing hazardous processes and products. Its function is to prevent the propagation of an accidental explosion from one building to another.

Cordite
A **Double-base Propellant** similar in composition to Ballistite, but with mineral jelly instead of camphor. The subject of a complex legal battle concerning the wording of Nobel's original patent for **Ballistite**.

Cordtex
See Detonating Cord.

Deflagration
Burning often leading to **Detonation**. A term often applied to **Low Explosives**.

Delay Element
A pyrotechnic element introduced between the **Fusehead** and base charge of a detonator designed to delay the detonation by a specific time.

Delay Detonator
A **Detonator** which has a **Delay Element** between the **Fusehead** and base charge to delay the detonation by a specified time, usually a fraction of second. A delay series enables controlled sequential firing for precision blasting.

Detonating Cord - Cordtex
An instantaneous detonating cord made by spinning a core of **PETN** into a textile plastic-covered cord. These cords are generally used as **Detonation** transmission lines for which purpose the core weight is usually 10 Grams per metre. Heavier cords are available for use as line charges, one use of which is in the linear seismic exploration systems, Geoseis and Aquaseis, where the cord is ploughed into the ground or paid out in water for geophysical prospecting purposes.

Detonation
The state of a chemical reaction which takes place in the material faster than the speed of sound, thereby producing a shock wave.

Detonator
The most important of Alfred Nobel's inventions. The trigger which is essential for the safe and controlled initiation of the explosive. A small device consisting of a metal tube with a small quantity of **primary explosive**, which in turn is initiated by a spit of flame. The flame can be provided by means of a **Blackpowder Safety Fuse** or an electrically-fired match-like fusehead. Conventional **Delay Detonators** are currently being augmented by a new generation of highly accurate electronically operated **Delay Detonators** for some applications.

Double-base Propellant
A propellant consisting of a mixture of **Nitro-cellulose** and **Nitro-glycerine**.

Dynamite
The first modern, cartridged **High-explosive**, and Nobel's most famous invention. It consists of **Nitro-glycerine** absorbed on an inert diatomaceous earth, **Kieselghur**, which soaks up the liquid rendering it safe to handle. It requires a **Detonator** to initiate and release the enormous power of the Nitro-glycerine. '**Dynamite**' has become a dictionary word for all explosives, but is no longer made. It has been replaced by a wide range of **Secondary Explosives**.

Edifas
A cellulose ether suitable for use in the food industry that was made at Ardeer. A particular use is in the preparation of meringues as a substitute for egg-white.

Electric Detonator
An electrically operated **Detonator**.

Fulminate
A **Primary Explosive** used in percussion caps and as a base charge in early **Detonators**.

Fuse
A flexible cord in which the core is either **Blackpowder** (slow burning) or **P.E.T.N.** (detonating), used to initiate remote **Detonations**.

Fusehead
The source of ignition in an **Electric Detonator**.

Explosive Fire-Suppressant Safety Systems
Systems of injecting fire suppressants into an incipient or established flame front to quench the flame before it can do damage or develop into explosive proportions. The systems detect the presence of flame by heat or pressure-sensitive detectors which then instantaneously trigger an explosive charge, dispersing the flame suppressant. These systems find extensive use as anti-explosion devices in fuel tanks in trucks and aircraft, dangerous chemical plants, and **gassy mines**, as well as in domestic fire-hazard situations such as hotel or tower-block lift shafts.

Explosive Welding

A relatively recent technique in which the extremely high temperature and pressure of the explosive shock wave is used to effect welding between metals. It is particularly effective with high-melting-point metals which are difficult to weld by conventional methods. It is also used to laminate exotic metals to structural base metal.

Flexel

A system of under-floor and wall heating, now superseded.

Gassy Mine

Generally a coal mine classed as dangerous because of the presence of methane which, when mixed with air, can become highly explosive (firedamp), and is a cause of devastating coal-mine explosions. No naked flame or means of ignition is allowed in such a mine, and only **Permitted Explosives** can be used.

Gelatines

A range of **Nitro-glycerine**-based **High Explosives** in which the **Nitro-glycerine** content is greater than 30%, and gelled with Nitro-cotton. Gelatines may be either Ammonium Nitrate based or Sodium Nitrate based (**Gelignite**).

Gelignite

See **Gelatines**.

Glycol

An ingredient essential in the manufacture of low-freeze **Nitro-glycerine** explosives. The quantity of Nitro-glycol in the nitrating mixture is determined by the severity of the low temperatures to which the explosive is likely to be exposed.

Gunpowder

A form of **Blackpowder** based on Bacon's classic formula (1242), used as a gun propellant.

Guncotton

A form of **Nitro-cellulose** made by nitrating cotton, and of a form suitable for a use as a gun propellant.

High Explosive

An explosives substance or mixture which invariably detonates when initiated, irrespective of the ambient condition of confinement (i.e. even in the open).

Kieselghur

An absorbent diatomaceous earth on which Nobel absorbed **Nitro-glycerine** to produce **Dynamite**.

Lead Styphnate

Lead Trinitroresorcinate. **A Primary Explosive**, used mostly in detonators.

Low Explosive

A solid mixture of chemicals which burn in the absence of air, but which, when confined, can burn to detonation. An example of a low explosive is **Blackpowder**.

Lyddite

A high explosive (trinitrophenol) widely used in munitions manufacture, also known as **Picric Acid**. Used previously as a dye in the textile industry before its explosive qualities were known.

Magazine

A building used to store explosives either in process or packed form. As is the case with explosives production buildings, **Magazines** are each licensed under the Explosives Acts legislation to hold a maximum permitted quantity of specific explosives.

Mercury Fulminate

The **Primary Explosive** chemical used in Nobel's first **Detonators**.

Nitrate

The key to most commercial explosives in that it provides the oxygen which, in combination with a fuel, provides the source of power when sensitised to explosion.

Nitration
The preparation of organic nitrates by the slow addition of the organic substance, usually an alcohol, to a mixture of strong nitric and sulphuric acids. The sulphuric acid effectively de-hydrates the alcohol, and the nitric acid replaces it with the nitro group of oxygen atoms that act as solid fuel in the explosive compounds.

Nitro-cellulose
Cellulose nitrate prepared by nitrating cotton linters with a mixture of nitric and sulphuric acids. There are many uses of nitro-cellulose. In celluloid films, cellulose paints and paint sprays, nail varnishes, lacquers and collodions etc. In explosives, the primary use is as a propellant and in the manufacture of Gelatine Explosives.

Nitro-cotton
A term used to describe forms of **Nitro-cellulose** used for a variety of purposes, the nature of which depends on the type of cotton and the extent of the nitration process. Uses include mixing with **Nitro-glycerine** to produce **Blasting Gelatine**.

Nitro-glycerine
Glycerine tri-nitrate, discovered by Ascanio Sobrero in 1846. An organic **Nitrate** and a molecular explosive (as distinct from a mixture of chemicals), which detonates in the open even when not confined. A **High explosive**, and principal component in many types of commercial **High Explosives**, the first of which was **Dynamite**, invented by Alfred Nobel in 1866. Too hazardous to use as an explosive in its natural form, but prior to the invention of dynamite, was used, despite the risks, for blasting (also known as **Blasting Oil**).

Nitro-glycerine Hill
A production unit producing **Nitro-glycerine**, constructed on a hill (usually artificially created) with the nitrator house at the top, the purpose being to take advantage of gravity by allowing the **Nitro-glycerine** and waste liquids to flow down hill through a sequence of wash, separator and labyrinth houses, usually via a network of lead-lined gutters and pipes, accumulated Nitro-glycerine being collected in a 'C' House. Dependence on gravity was essential as pumping Nitro-glycerine can cause detonation.

Passive Restraint Systems
A recently introduced safety system for automobiles to protect the driver and passenger from serious injury by providing an air cushion which automatically inflates in the event of collision. The necessary immediate response is provided by a small explosive charge.

Permitted Explosive
A very important class of explosives specifically designed to be used with safety in **Gassy Mines** (e.g. coal mines). Today, they consist essentially of a low percentage of **Nitro-glycerine** and a mixture of ammonium nitrate and sodium chloride (common salt). The sodium chloride, being an alkali halide, is a flame suppressant and is the ingredient that affords the safety to the explosive when it is fired in the presence of methane and air (potential firedamp).

P.E.T.N.
Pentaerythritol tetranitrate. A very stable **High-Velocity-of-Detonation** (V.O.D.) crystalline organic nitrate and one of the most powerful and brisant high explosives. Its main use is as a base charge in high-efficiency detonators (to minimise the quantity of primary explosive required for initiation), and for detonating cord (Cordtex)

Picric Acid
Trinitrophenol. A high explosive, also known as **Lyddite**, with origins as a yellow dye in the textile industry. More brisant than **TNT**, and used primarily for military applications.

Powder Train
A primitive trail of blackpowder used as a fuse to detonate an explosive charge. Now rarely seen, except in the Cinema.

Power
Explosives **Power** is the ability of the explosive to do work and is dependent upon the enormous amount of gas produced from a relatively small amount of solid or liquid explosive when it detonates. The **Power** of an explosive is classified by comparing it to the work done by a similar quantity of the most powerful commercial explosive, **Blasting Gelatine**, which is used to define the datum of 100%.

Primary Explosive
A single explosive substance which detonates when subjected to flame. The principal use is in detonators, examples including **Mercury Fulminate** and Lead Azide.

Propellant
An explosive material (which may be solid or liquid) with a low rate of combustion which is used for its propulsive effect. **Propellants** are also sometimes refered to as Propulsives.

Safety Fuse
A slow-burning fuse in which the core is **Blackpowder** within an external spun sheath. The fuse is used to ignite the **Detonator** and provide a delay (usually of specific duration) between the lighting of the fuse and the initiation of the **Detonator** and the subsequent explosion. Normal fuses burn at approximately 1cm per second.

Secondary Explosives
Explosives or mixtures of explosive substances which require a **Detonator** to initiate the composition to **Detonation**.

Seismic Explosive
Explosives specifically designed for geophysical prospecting for oil and gas. This class of explosive is of relatively recent origin and functions by providing an explosively produced earth tremor whose passage through the earth can be traced by seismic instruments. The analysis of the trace enables a three-dimensional map of the earth's strata to be drawn in order to determine the location of potential oil or gas reserves. Systems are available for both terrestrial and off-shore exploration.

Shaped Charges
Explosive devices in which the end of the charge is in the form of a cone depression. This depression focuses the explosive force into a high-penetrating jet. Used in perforating charges such as those for steel furnace tapping and well-hole blasting.

Single-base Propellant
A propellant consisting primarily of **Nitro-cellulose**.

TNT
Trinitrotoluene. A stable crystalline organic **Nitrate** explosive less powerful than **Nitro-glycerine**, and used mainly in military explosives. Also has had a use in some specialist commercial explosives.

Triple-base Propellant
A propellant consisting of a mixture of **Nitro-cellulose**, **Nitro-glycerine**, and smoke suppressant.

Velocity of Detonation (V.O.D.)
The speed of the **Detonation** shock wave which usually varies from 2,000 to 8,000 metres per second (the speed of sound being 331 metres per second).

Water Gel
One of the current generation of non-**Nitro-glycerine** explosives (including emulsions) consisting essentially of a water suspension (gel) of ammonium nitrate sensitised with either a high-efficient fuel or by aeration. Low impact sensitivity nitro-compounds can also be used as sensitiser.

1. For a more detailed account of the history of high explosives, see Taylor, J (1951) and Dolan, J E (1985).

2. Technical sources on the development of mining explosives include Taylor and Hancock (1947), Taylor and Gay (1958) and McAdam and Westwater (1958).

3. Sohlman, R (1983), p34.

4. Taylor, J (1951).

5. There are a number of sources of information on the life of Alfred Nobel, the most comprehensive of which is Schluck, H and Sohlman, R (1929).

6. Schluck, H and Sohlman, R (1929), p157.

7. Sohlman, R (1983), p28.

8. Schuck, H and Sohlman, R (1929), p126

9. Bergrengren, E (1962), which contains a special supplement by N K Stahle on the Nobel Institutions and Prizes.

10. Bergengren, E (1962), p129.

11. Sohlman, R (1982), p40-2.

12. Bergengren, E (1962), p63-4.

13. Imperial Chemical Industries (1938), p18

14. Nobel's Explosives Co. Ltd (1907).

15. Noted in an internal report at Ardeer by T Taylor (1923), entitled, *An Outline History of Ardeer.*

16. Miles, F D (1955) provides details of the history of research within the Nobel Division of ICI.

17. Trail, D (1946).

18. Marke, D J B and Lilly, C H (1951)

19. Reports to the Secretary of State by HM Inspectors of Explosives concerning accidents were standard procedure and required by the Explosives Acts, being published by HMSO. A typical example was that produced by Captain J H Thomson, HM Chief Inspector of Explosives in 1902 (cd 1045), entitled, *'Circumstances Attending an Explosion of Nitro-Glycerine which Occurred in one of the Final Wash-houses of the Factory of Nobel's Explosives Company Limited at Ardeer, near Stevenston, Ayrshire, on 9th January 1902. In this particular accident, one man lost his life.*

20. Imperial Chemical Industries (1938), p30.

21. HMSO (1956)

22. Imperial Chemical Industries (1938).

23. Nobel's Explosives Co. Ltd (1907), p44.

24. Reader, W J (1970), p70-2.

25. Trail, D (1946).

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Explosives

In 1871, Alfred Nobel brought the newly-born high-explosives industry to Britain, establishing, with the backing of Scottish entrepreneurs, the country's first Dynamite factory at Ardeer on the west coast of Scotland in Ayrshire. In its time, Ardeer grew to become the largest explosives factory in the world, and was one of the principal driving forces behind the creation of ICI in 1926. Through the publication of this book, the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) and ICI Explosives wish to acknowledge the debt that Scotland, the United Kingdom and the World owes to Alfred Bernhard Nobel.