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Yoel Bergman

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The Technological Need: Abel & Dewar's Primary Motive for Inventing Cordite in 1889

YOEL BERGMAN*
Tel Aviv University, Israel
Email: yoel@hospitech.co.il

ABSTRACT
By the 1880s, smokeless military propellants greatly outperformed traditional black gun powders, as first shown in France in late 1884. In early 1889, the British version of a smokeless propellant for the military, Cordite, was developed by Sir Frederick Abel, a renowned War Office chemist and by Professor James Dewar from the University of Cambridge. They tested Alfred Nobel's 1888 British patented smokeless Ballistite but rejected it for a major flaw, while upgrading it to obtain Cordite in 1889. At first glance, the motive for rejecting Ballistite might be seen as driven by personal profit, but considerations of monetary gain, were actually of secondary importance. Abel and Dewar's primary motive for rejection was technical and was ultimately proven valid: Nobel made major corrections to his Ballistite patents including his correction of the flaw Dewar and Abel had noted.

Introduction

Until the mid-nineteenth century, black powder was the only gun propellant used in artillery and small arms, with the greatest impetus for new and better compositions coming from the advanced in small firearms. It was recognized by arms developers that a decrease in the gun calibre would yield a number of ballistic and tactical advantages, provided that an increase in initial velocity could be achieved to balance the loss of the lower projectile weight as a consequence of the decreased barrel diameter. As far as black powder was concerned, its limit of efficiency had been reached by the middle of the eighteenth century. About that time, a search for new propelling substances began. The organic nitrate explosives nitrocellulose, a fluffy

*Dr Yoel Bergman is an Associate Researcher at the Cohn Institute of Tel Aviv University and is interested in the history of military technology, with an emphasis on gun propellants.

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material, and nitroglycerine, a liquid, appeared in the mid-nineteenth century and both were candidates for scientific investigation.[1]

To adapt nitrocellulose as a gun propellant, much effort was needed to tame its uncontrolled combustion, especially for military use. As such, and until the mid-1880s, much of the nitrocellulose produced for energetic purposes was used in explosives, with some in hunting gun powder formulations, where it was mixed with black powders. These efforts to adopt it for the military achieved success in late 1884 when a dependable gun propellant composition, Poudre B, was developed in France. This had a 96% nitrocellulose content in the formulation. A recent paper proposes that the Poudre B formulation was developed within only a few weeks, during October and November 1884, beginning with the testing of celluloid (82% nitrocellulose, 18% camphor) and soon, by dispensing with the camphor, reaching the more energetic Poudre B composition in the shape of flakes.[2] The Poudre B's ballistic potential was quickly appreciated, when, only a month later in December 1884, Poudre B now shaped in ribbons, was tested in a 65 mm cannon and demonstrated its superior ballistic advantage to black powder. The next year was devoted to adopting the powder in flake form to the newly developed semi-automatic 8 mm diameter Lebel rifle, which was introduced in 1886.[3] From that year, and until 1900, Poudre B was adopted for large cannons of various size in the French army and navy, and with only slight changes in composition and grain shape over time.[4] By 1900, 72% of French military propellants were Poudre B types. In the same period Cordite, the first British smokeless military propellant, was jointly developed by Professor James Dewar from the University of Cambridge, and Sir Frederick Abel, a renowned War Office chemist. In 1898, and soon after adapting Cordite for the Lee-Enfield 0.303-inch standard rifle in 1895, the Waltham Abbey government plant was also manufacturing Cordite for the Royal Navy's 12-inch guns.[5]

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[1]Heinrich Brunswig, trans. and annotated by Charles E. Monroe and Alton L. Kibler, *Explosives, a synoptic and critical treatment of the literature of the subject as gathered from various sources,* (New York: J. Wiley & Sons, 1912), p. 241.

[2]Yoel Bergman, 'A New Perspective on Poudre B's 1884 Development', in Liliane Hilaire-Pérez et Catherine Lanoë (Dir.), *Les sciences et les techniques, laboratoire de l'Histoire. Mélanges en l'honneur de Patrice Bret,* (Paris: Presses des Mines, collection Histoire, sciences, techniques et sociétés, 2022), p.198 & pp. 209-210.

[3]Ibid., p. 198 & p. 202.

[4]Yoel Bergman, '*Development and Production of Smokeless Military Propellants in France 1884–1918'*, Ph.D. dissertation, (Tel Aviv University, 2009), pp. 81-82. https://www.researchgate.net/profile/Yoel-Bergman/research. Accessed 10 August 2022.

[5]Edward William Anderson, 'The Machinery used in the Manufacture of Cordite', in *Proceedings of the Institution of Civil Engineers,* Paper No. 3075 (1898), p. 70.

Ballistite, a powerful smokeless propellant was first patented on a provisional basis in Britain by Alfred Nobel on 31 January 1888.[6] He had added, for the first-time, nitroglycerine to smokeless propellants which previously had all been based on nitrocellulose, as for example used in Poudre B. Nobel's complete patent specification in Britain was applied for on 28 December 1888 and was approved on 15 January 1889. This patent was more technical and precise in nature, recommending as an optimal formulation, 46% nitroglycerine, 46% nitrocellulose, and 8% camphor. The mid-1889 formulation for Cordite, contained 58 % nitroglycerine, 36 % nitrocellulose and 5% petroleum jelly. The nitrocellulose used in Ballistite was specifically of the soluble form (in an ether-alcohol solution), while that used in Cordite was of the insoluble and more energetic form. The soluble form is known scientifically as di-nitrocellulose, and more commonly as Collodion. The insoluble form is known as tri-nitrocellulose and more commonly as Guncotton. This difference would later become an important legal issue.

Nobel was a determined entrepreneur, industrialist and a talented inventor in explosives and in other areas. Yet he lacked the scientific education of Abel and Dewar, the inventors of Cordite. In the 1860s he had invented and then sold the explosive Dynamite which is based on nitroglycerine mixed with a porous siliceous earth. In the 1870s, he had patented and sold the more powerful Blasting Gelatine, basically composed of nitroglycerine and soluble nitrocellulose, the same key ingredients that he used in the later Ballistite. He held patents and owned plants across Europe and intended to produce and market Ballistite internationally as he had done for his other explosives.

Ballistite's development was long, taking some eight years, and only ended in late 1887. At that time Nobel was missing for long durations, due it seems, to business needs. Research was conducted in Nobel's laboratory in Paris and field testing was performed by Nobel's Explosives Company in Ardeer, Scotland. To achieve Ballistite, Blasting Gelatine was modified to make it less explosive – a property needed for propellants, by changing the manufacturing process and by using new substances in small quantities, most notably camphor. This adds doubt to what Nobel wrote at the beginning of his patent, that Ballistite was a modification of celluloid, where part of the camphor was replaced by nitroglycerine. This seems to contradict his claim that Ballistite resembled Blasting Gelatine, with appropriate changes in process and substances. The addition of camphor, as indicated by Mauskopf, was made in the very last phase of Ballistite development. Until then, samples were made principally of nitrocellulose and

[6]Alfred Nobel, 'Improvements in the Manufacture of Explosives', English Patent No. 1471, 31 January 1888 (Provisional Specification).

nitroglycerine, thus supporting the theory that he began with Blasting Gelatine.[7] One can question how much scientific consideration Nobel gave to adding the volatile camphor. Another unanswered question is why was it so important for Nobel to indicate that Ballistite was a modification of celluloid. Was the addition of camphor intended to support the major claim made in his patent – the celluloid modification.

Smokeless propellants, when compared to black powders, are stronger mechanically since they do not disintegrate when fired in the gun as does black powder, thus assuring almost equivalent ballistic results from shot to shot. This is caused by the presence of the strong solvated, nitrocellulose matrix. This burns cleaner with almost no residues and produces much less smoke and thus does not disclose the firing position as well as enabling semi or fully automatic firing. Such formulations also have higher potential chemical energies and burn in a controllable manner, resulting, for example, in higher exit velocities for the same maximum pressure. One drawback, which appeared in the early 1890s was, however, a dangerous instability in long term storage, that was not found when storing black powders. This was due to nitrocellulose decomposition and the release of a gas at high pressure and temperature, leading to a number of large storage explosions during the early years following the adoption of smokeless propellants. Nobel, either due to requirements from countries such as Italy or through his own initiative, added a stabiliser in mid-1889.[8] In France, a suitable stabiliser had not been selected until the early 1900s following some notable storage explosions. With Cordite, the addition of 5% of petroleum jelly in the formulation ensured its chemical stability, an unintended but beneficial outcome. During the early development of Cordite Abel and Dewar had added the petroleum jelly with the intent that it would remain in the bore after each shot, thus 'lubricating' the bore before the next shot and so reduce barrel erosion due to Cordite's generation of high temperature combustion gasses. The jelly did reduce erosion, but not by lubrication. Being an endothermic substance, the jelly drew out heat and lowered the gas temperature which was increasing the barrel erosion. Another unexpected outcome was the jelly making Cordite chemically stable, without a specific stabiliser addition being needed.

France's early development and use of smokeless propellant was officially disclosed in an 1890 bulletin by the Minister of War. This announced that French armament had

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[7]In 2008 Seymour Masuskopf generously provided the author with a copy of his draft review of Nobel's recollections. It noted that camphor was only tested seriously just before Nobel's filing of the first patent in Paris in late 1887. Most experimental formulations before 1887 did not contain camphor. The presence of camphor in practice and patents was subsequently and quickly dropped.

[8]Yoel Bergman, 'Alfred Nobel, Aniline and Diphenylamine', *ICON,* Vol. 17 (2012), pp. 64-66.

undergone an almost complete transformation in the last five years (1885-1890), a change which most great continental powers were then also striving to realise.[9] The advent of Poudre B for use in French military rifles and after that in artillery, and Nobel's 1887 to early 1889 patents in Europe, seem to have created a typical 'me too' syndrome in different countries. Each was quick to strive for the smokeless explosive's tactical advantages. By 1889, Tsar Alexander III had urgently ordered work on 'rifles of reduced calibre and cartridges with smokeless powder'.[10] In Britain, it was the Prince of Wales in 1888 who asked (or instructed) that an Explosives Committee be formed, and required Abel to serve as its head. The prince had shown a great deal of interest in Guncotton (or insoluble nitrocellulose) and attended lectures and demonstrations by Abel and others. Abel was a confidante of the prince and attended many of his dinners and social functions.[11] In Italy, where Nobel's company was very active, the Italian government signed a production and supply contract with Nobel in August 1889.[12] As military rifles were the first in line for black powder replacement it was first adopted for rifles such as the French Lebel in 1886, the British Lee-Enfield in 1895, and the Russian Mosin. The first Ballistite production for Italy in late 1889-1890 was made for the Italian military rifle.

The official appointment of Abel to establish and lead the Explosives Committee came from the Commander-in-Chief of the Army, the Duke of Cambridge, in the summer of 1888, and Abel directed the Committee from July 1888 to 1891 with Dewar also a key member. The committee was formed to select a modern propellant for the military, which wanted a smokeless type. Samples of smokeless Ballistite, patented by Alfred Nobel in Britain, were sent by Nobel to the Committee and were test fired in late 1888 using a British 0.303-inch military rifle.[13] After some changes by Nobel, Ballistite complied with the Committee's ballistic requirements. In more official comparative tests in 1890, using Cordite versus Ballistite in the 0.303-inch rifle, it was concluded that the ballistic results were very similar, but in detonation tests, Ballistite was more sensitive.[14] It is worth noting that due to the similar energies produced by

[9]Bergman, A New Perspective, pp. 197-200.

[10]Michael Gordin, 'No Smoking Gun: D.I. Mendeleev and Pyrocollodion Gunpowder', in *Instrumentation, expérimentation et expertise des matériaux énergétiques (poudres, explosifs et pyrotechnie) du XVIe siècle à nos jours*. *Actes des Troisièmes Journées Paul Vieille, Cité des sciences et de l'industrie, 19–20 octobre 2000*, (Paris: A3P & CNRS, 2001), p. 75.

[11]John Williams, *The History of Explosives, Volume II: The Case for Cordite* (UK: J. Williams, 2014), p. 5 & p. 240.

[12]Yoel Bergman, 'Nobel's Russian Connection: Producing and Marketing Ballistite', 1889–1890, *Vulcan,* Vol. 2 (2014), p. 43.

[13]Alfred Nobel, 'Improvements in the Manufacture of Explosives', English Patent No. 1471, 28 December 1888 (Complete Specification).

[14]John Williams, *The History of Explosives,* p. 251 & p. 254.

both compositions, and due to the non-ballistic efficiencies of their grains at that time, the differences in ballistic results were minute. Cordite's ballistic efficiency advantage would only be realised later, by the extrusion of cylindrical grains with inner perforations, which were especially useful in higher calibres. Nobel in understanding this Ballistite flaw, was also trying to remain within the competition. His 2 August 1889 update to his 1888 British patent, submitted also in parallel in Italy, proposed to create perpendicular perforations in the sheets or carpets, coming out of the Ballistite process and which were then rolled into the cartridges.[15] It appears this was an attempt to compensate for the lack of ballistic efficiency. During gun combustion, the very small diameter perforations allow the flame to enter inside the cartridge. As propellant combustion progresses the outer surfaces of the sheet is ablated producing less gas and lower pressures in the combustion chamber and at the projectile base, pushing it more slowly. This is partially compensated by the increase of inner perforation surfaces and diameters due to flame ablation. In the Cordite extrusion, granular cylinders, each with one large inner perforation, could be easily made into a tube, or into cylinders with seven or more small perforations. On this point, one article has recently proposed that such perforated sheets were sent to France by Nobel from his Italian Avigliana plant, sometime in mid-1889.[16] At that time, the French military were also undertaking tests and the samples seem to have been intended for the French 90mm cannon.[17] Nobel continued in improving the efficiency of his propellant. In his 1896 international patents he proposed what would later become commonplace in small arms, the coating of the propellant grains with slower burning materials.[18]

Some of the Ballistite samples received from Nobel in 1888 were, as was customary, examined at high storage temperatures. They were found to release the camphor, which potentially could change Ballistite's ballistic performance over time. Under the terms of the test programme Abel and Dewar, were allowed to make changes to candidates' formulations, and they created an experimental powder without camphor. This required significant differences to the Ballistite production process, formulation and shapes, and was soon labelled Cordite. The first Abel and Dewar provisional patent of 2 April 1889, was submitted in Britain and without royalties, and began with what seems unusual for a patent, by denouncing the recent addition of camphor to Blasting Gelatine, to create a propellant and so pointing indirectly at Ballistite – since

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[15]R. Schuck & H. Sohlman, *The Life of Alfred Nobel,* (London: Heinemann, 1929), p. 274.
[16] Yoel Bergman, Alfred Nobel, Aniline and Diphenylamine, p.59.
[17] Yoel Bergman, 'Fair Chance and not a Blunt Refusal: New Understandings on Nobel, France, and Ballistite in 1889', *Vulcan,* Vol. 5 (2017), pp.31,33-34.
[18]Alfred Nobel, 'An Improved Manufacture of Explosives', English Patent No. 27197, 30 August 1897 (Approved posthumously).

Nobel claimed in his 1888, patent, that Ballistite resembled Blasting Gelatine.[19] The same denouncement was soon found in their Swiss Cordite patent of June 1889.[20] Unlike in Britain, the Abel and Dewar patents filed abroad did expect royalties.[21] Such criticism of camphor was warranted, as by mid-1889 Nobel had removed camphor from Ballistite, claiming later that other governments with which he worked had asked him to do so. He also made other significant changes, especially in the initial mixing process, and this pointed to the prematurity of his 1888 patents.[22] Abel, being aware of Nobel's intention to make changes in early April 1889, claimed that such changes resulted from the British Explosives Committee's criticism. Since Cordite's shape and production stages were very different, it became in the long run, much more useful for various calibres, both in Britain and abroad. Cordite could be created with less energetic compositions than Ballistite, thus reducing barrel erosion and producing more ballistically efficient grain shapes. Ballistite was eventually mostly reserved for use in mortars, which are less affected by barrel erosion. One example for such flexibility was in the lowering of Cordite's nitroglycerine content after finding that Cordite had created too much cannon barrel erosion during the Boer War.

Some in the British Parliament and press, felt that Cordite was really a fake Ballistite and that Abel and Dewar had abused Nobel's knowledge in their quest for Cordite and quest for personal gain through the overseas patents. Nobel's company in Britain filed a lawsuit claiming patent infringement. The 1894 lawsuit and two subsequent appeals by Nobel ended in failure due to a crucial legal point, and one which might seem to the public to be a minor technical point, namely Cordite's use of a different, insoluble form of nitrocellulose. This difference, although claimed in the trial to have stemmed from Cordite's integrity needs, could also have been derived from a process necessity. Nevertheless, this emphasis on nitrocellulose differences at the trial much obscured other, more meaningful, technological considerations in the manufacture of Cordite.

Between late 1887 and early 1889 Nobel had submitted his first Ballistite patents in France, Britain, Italy, and Spain.[23] In the 1894 British trial, Nobel said that these initial patents were intended to protect his innovative nitroglycerine-based propellant and allow early entry to the market while protecting it from being blocked by others. He

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[19]Frederic A. Abel and James Dewar, 'An Improvement in the Manufacture of Explosives', English Patent No. 5614, 2 April 1889 (Provisional Specification).

[20]Frederic A. Abel and James Dewar, *'Perfectionnement dans Les Munitions de Guerre'*, Swiss Patent No. 1189, 25 June 1889.

[21]Mathew C. Ford, *'The British Army and the politics of rifle development, 1880 to 1986'*, Ph.D. dissertation. (King's College, 2008), p. 86.

[22]Bergman, Alfred Nobel, Aniline and Diphenylamine, pp. 61-64.

[23]Ibid., p. 61.

expected that royalties would be paid to him by governments who adopted or adapted his discovery. For this reason, he had paid less attention to patents details.[24] Such a move can explain why what we would now consider to be major patent aspects were not sufficiently detailed in his early applications. Despite this Nobel's biographers have praised Ballistite's utility from the mixing of two powerful explosives to deliver the less powerful Ballistite propellant. Yet, as written elsewhere, where propellants are concerned, the chemical makeup alone was not enough. Concerns were raised by different governments regarding process safety when using nitroglycerine (by France and Russia), long term storage stability (Britain), barrel erosion (France), and the ballistic advantage of Ballistite over Poudre B (France).[25] In France, despite concerns over barrel erosion, Ballistite was considered in 1889 for the Lebel rifle, but the results seem not to have been better than the French smokeless Poudre B – a possible reason for its rejection that has not previously been recognised in the literature on this topic.[26]

By early 1889 Abel and Dewar, disappointed with the Ballistite's camphor issue, had begun work to improve the formulation. When the British government adopted and began to produce Cordite in the early 1890s, Nobel's British company became concerned at losing future income and filed the 1894 lawsuit.[27] It was soon compensated by taking part in Cordite production.[28] A 1923 report, marking the fiftieth anniversary of Nobel's establishment of the Ardeer factory in Scotland, noted that in 1898 Ardeer was producing Cordite mixtures (or pastes) in large quantities for further processing into final product at the government plant at Waltham Abbey.[29]

As a background to justifying Abel and Dewar's technological reasons as the primary motive and profits as the secondary motive, we will first review the ethical and legal aspects of the story, which won a large part of researchers' attention, based on the recent work by John Williams, Mathew Ford, and Seymour Mauskopf.

Ethical Criticisms

These can be found in contemporary accusations made against Abel and Dewar by the press and key figures, both before and during the trial. In their understanding, Nobel had been asked in late 1888 to send samples to the Committee, which soon decided

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[24] John Williams, *The History of Explosives,* p. 313.
[25] Bergman, 'Nobel's Russian Connection', pp. 49-51.
[26] Yoel Bergman, 'Fair Chance and not a Blunt Refusal', pp. 32-36.
[27] Clive Trebilcock, 'A Special Relationship - Government, Rearmament, and the Cordite Firms', *Economic History Review,* Vol. 19 (1966), p. 368.
[28] R. Schuck and H. Sohlman, *The Life of Alfred Nobel*, p. 123.
[29] T. Taylor, *Report on Ardeer Factory - An Outline of its History, 1873-1923,* (Scotland: Nobel's Explosives Co., Ltd., Ardeer factory, Stevenson, Ayrshire, 1923), p. 22.

to improve upon them, eventually culminating in Abel and Dewar's own Cordite patents in Britain and abroad. Some believed Nobel to have been abused, by having been invited to support the tests by submitting samples and commercially sensitive technical information which was then used by Abel and Dewar to create Cordite.[30]

Abel and Dewar already had a reputation before the trial of being very interested in monetary gain from consulting and patents. Their quick move to personally patent Cordite not long after their asking Nobel for samples, while made in their official capacity seemed to underscore a quest for profit. Another accusation was made by the inventor Hiram Maxim, who claimed to have proposed to the Committee a powder similar to Cordite and made before Cordite had been patented. He suggested that Abel and Dewar had blocked others in advancing their own propellants.[31]

Part of the reasons for the ethical scandal can be understood as a repeat of a pattern set before by Abel. In 1862 an Austrian patent for producing nitrocellulose was first registered in Britain by the Baron Von Lenk, a pioneer in the use of Guncotton as an explosive and propellant in Austria. In his 1865 patent as a War Office employee, Abel filed an improvement patent, at a time when government employees were not officially allowed to file personal patents. He added a final purification step that helped to partly resolve the stability problem.[32] Abel did not notify the War Office of his patent, but instead sold it to a Guncotton factory in Stowmarket, Suffolk, which had previously employed Lenk's process but was dissatisfied with it following an explosion. Soon after the patent's issue Abel campaigned against imported explosives based on nitroglycerines (i.e., Dynamite), and the Shultze powder produced in Germany, a combination of wood derived nitrocellulose mixed with salts and intended for sportsmen. He claimed they were both unsafe. Yet Abel's purification step and claim that his nitrocellulose was safe did not prevent the explosion of some ten tons of Guncotton at Stowmarket in the summer of 1871 which killed tens of people. Following the accident, and public criticism of Abel, the government became aware of his patent and forced Abel to sell it. Williams even suggests that the government was equally unaware of the Abel and Dewar Cordite patents filed in continental Europe in 1889.[33]

Despite the Stowmarket accident, Abel's process was accepted as state-of-the-art. For example, a French navy report of 1880 indicates that 100 tons of nitrocellulose were ordered from Stowmarket in 1875, and 35 tons in 1877 to be produced by the Moulin-Blanc plant in France. The French navy said both nitrocelluloses had been produced

[30]Trebilcock, 'A Special Relationship', p. 376.
[31]Ford, *The British Army,* p. 86.
[32]Frederick Abel, 'Purification of Nitrocellulose', English Patent, No. 1102 (1865).
[33]John Williams, *The History of Explosives,* pp. 89-190.

by the Abel process. Stowmarket also supported the Moulin Blanc engineers.[34] Paul Vieille, the inventor of Poudre B indicated in an 1886 report that the nitrocellulose in Poudre B was made by the Abel process. He reviewed the storage history of nitrocellulose stored in France for more than 10 years and concluded that it was stable enough and, for this reason, Poudre B would also be stable in long term storage.[35] This turned out to be incorrect due to early 1890s storage explosions in France, which led to the introduction of an unsuitable stabilizer in the mid-1890s. In the case of nitrocellulose, Abel's patent improved a foreign patent in chemical stability, and in Cordite, improved the ballistic stability and performance of Ballistite. At the same time, he secured for himself profit opportunities e.g. Stowmarket was paying him royalties for his Guncotton process by the mid-1860s while the Cordite patents submitted in continental Europe were intended to have the same result. Profit and scandal issues asides, one could say that his changes to the foreign patents had much improved the quality and performance of British armaments.

The public discovery that Abel and Dewar submitted Cordite patents abroad resulted in a political scandal in Britain as they had supposedly revealed British achievements to foreigners.[36] Robert William Hanbury, Member of Parliament for Preston, and a watchdog of all armament questions, was vocal in criticising their patriotism and ethics. The War Office sprang to their defence and established the 'Cordite Scandal' as one independent of personalities but deeply rooted in the department's system of innovation by committee.[37] Nevertheless, Lord Rosebury's Liberal Government was forced out of office in 1895, due in part it is said, to War Office mismanagement, which among other outcomes had given rise to the Cordite Scandal.[38]

The Legal Aspects

These stem mostly from the 1894 trial and from Nobel's subsequent appeals. The trial aroused interest due to the intricate strategies of both sides, and the conflict between the real actors, Nobel on one side and Abel and Dewar on the other. It also became influential on British patent law by emphasising a new legal importance for precision in the writing of patents. Nobel's lawyers argued that the 1888 Ballistite patent was a revolutionary master patent covering future small variants, such as the later Cordite. The judge believed that the core issue was how exact were the claims in the 1888 patent. Much of the trial was devoted to textual analysis, especially on whether a key ingredient, the insoluble tri-nitrocellulose type used in Cordite was covered by

[34]Yoel Bergman, 'The Moulin Blanc Nitrocellulose Plant in France - Process and Improvements in the 1880's and early 1890's', *ICON,* Vol. 13 (2007), pp. 24-25.
[35]Ibid., pp. 25-26.
[36]John Williams, *The History of Explosives*, p .294.
[37]Trebilcock, 'A Special Relationship', p. 376.
[38]Ford, *The British Army,* p. 85.

Ballistite, which prescribed use of soluble di-nitrocellulose. Nobel's experts argued that the differences between the two were scientifically blurred.

In a change made to the July 1889 cordite patent Abel and Dewar indicated that with theirs was an insoluble process, with a consistent dough for extrusion obtained, and it also emphasised that the insoluble was different from the soluble process. Such emphasis seems to have been made to distinguish Cordite from Ballistite, perhaps in view of a future lawsuit. In the trial, the reason for changing to insoluble was explained by Abel and Dewar as being due to an early observation that the soluble nitrocellulose did not hold the nitroglycerine strongly enough at low temperatures.[39] This author believes the change to a less soluble nitrocellulose may have also been driven by process requirements. An insoluble process was needed because when soluble nitrocellulose is mixed with solvents and liquid nitroglycerine, a dough is obtained that is too soft for extrusion. The French Poudre B process, similar to Cordite, also used an insoluble process.

The court ruled that the insoluble process was not covered by the Ballistite patent. Nobel lost the case on this ground and failed again in two appeals on the same issue, the last one ending in the House of Lords in 1895. The production process differences in Cordite raised by Abel and Dewar in the trial received less importance. Although the judge had agreed that the processes were not identical, it was the material question that mattered.[40]

The Personal Aspects

Historic and problematic relations existed between Abel and Nobel and merit examination, since they might have prompted Abel to invent Cordite in response to their previous scientific competition. Soon after his nitrocellulose patent issuance in the 1860s, Abel advised British legislators in the late 1860s and early 1870s only to use Dynamite under technical limitations due to the presence of nitroglycerine. One likely reason for the advice was the advancement in use of his improved nitrocellulose as an explosive. At that time this was its only use. Prestige could have also played a part when, in 1867, Abel took out a patent for an explosive named Glyoxiline, which resembled Nobel's future Blasting Gelatine. Abel's was based on mixing nitroglycerine and nitrocellulose, but failed commercially. Nobel's major success with the nitroglycerine-based Dynamite from the 1860s, would have been problematic for Abel as a result. The mid-1870s success of Nobel's Blasting Gelatine would have been even more annoying. Here, Nobel succeeded with an explosive based on nitrocellulose and

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[40]Seymour Mauskopf, 'Nobel's Explosives Company, Limited v. Anderson (1894)', in Jose Bellido ed., *Landmark Cases in Intellectual Property Law,* (New York: Bloomsbury, 2020), p. 128 & pp.132-133.

nitroglycerine, whereas Abel had failed. One testimony to his feelings comes from the Journal of the Society of Chemical Industry of 29 July 1883, where Abel was quoted as saying that he had been in 1867 on the verge of preparing what became one of Mr Nobel's greatest triumphs, the remarkable explosive agent, Blasting Gelatine.[41] Thus, Ballistite weaknesses in late 1888 and the need for a British smokeless propellant may have created an opportunity for Abel to demonstrate his inventive superiority. Prestige can therefore be considered another motive,

The Technological Aspects

It is plausible to assume that Abel and Dewar had only Ballistite at hand in late 1888, as a long developed and gun-tested, smokeless formulation. The forming of the Committee back in mid-1888 to examine candidates from the industry, suggests that smokeless development was either lacking or in its first phase for the British military.

In late 1888, the two sides worked together on improving Ballistite ballistic performance. Ballistite samples were test fired, sometimes in Nobel's presence and he made improvements. By early January 1889, his samples met the ballistic requirements for a military rifle.

But things then became problematic. The samples received at the end of 1888 had a strong smell of camphor. This material was needed in Ballistite to facilitate dissolution between nitroglycerine and nitrocellulose and to reduce Ballistite's energy. Abel and Dewar exposed the Ballistite samples to high temperatures to check its behaviour. Under these conditions it was found that camphor volatised out of the formulation. This had the potential over time to change the nominal ballistic performance after high temperature storage as found on warships. Nobel, who seemed confused, said that the samples were made in a hurry and promised to resolve the problems.[42] In the British context, the Ballistite acceptance tests provided important knowledge, in the positive and negative sense, helping Cordite. Obviously, Nobel and others felt that he was being used, yet they overlooked the technical reasons for Ballistite rejection. Much of this would have been prevented if all three had worked for the same organisation, for instance the War Office, and without differing organisational loyalty and commercial aims. Nobel would have been the initiator of a new formulation with Abel and Dewar his colleagues, correcting inherent errors in production and formulation, and all would have ended happily with Cordite. Such an ideal project was found in France during 1884-1886 in the invention and adoption of the first military smokeless powder, Poudre B. The scientists, engineers, and field testers all worked directly for the French government.

[41] John Williams, *The History of Explosives,* p. 102, p. 169, pp. 176-177

Nobel's tests to meet British requirements based on trial and error, resemble his tests in France in mid-1889. Through Nobel's high level political connections, the Minster of War was persuaded to test Ballistite in the Lebel rifle, which was already performing extremely well with Poudre B. The field tests seemed to produce unimpressive results and the Ministry of War had soon sent suggestions to improve the samples that had been sent. Subsequent improvements if made, do not seem to have helped.[43] Several months after the final rejection, Nobel, in his 31 August 1890 letter to the Russian Minister of War on the status of ballistite in European countries, accused the 'inertia' of the French State engineers as the reason.[44] He also wrote that Cordite was a forgery, while better ballistic results were found with Ballistite.[45] His stated disappointments from France and Britain, may have been caused by his commercial displeasure at losing income, and from anger for being rejected as an inventor, who had had previous worldwide successes. The letter reveals difficulties in being accepted in Germany and Russia and other, smaller countries, while championing the acceptance of Ballistite by the Italian government. Here it is logical to assume that Italy took Ballistite because its development and production were not yet well established.

After being presented with the camphor issue, in late 1888, Nobel seems to have been little convinced that camphor needed to be removed. Evidence can be found in an early 1889 visit by a British committee member who visited Nobel's laboratory in France. He reported to the committee in late March 1889 that the Ballistite formulation and process were still being changed, and camphor was still present (6%).[46] He also found that traces of the stabiliser aniline had been added.[47] In addition, in his first US submission in the same month, March, Nobel still kept camphor.[48] Dropping the camphor is first found in the July 1889 German patent where Nobel

[43]Bergman, 'Fair Chance and not a Blunt Refusal', pp. 33-34.
[44]Bergman, 'Nobel's Russian Connection', pp. 48.
[45]Ibid., p. 54. Note that the said article was the first to discover Nobel's connection with Russia on the Ballistite issue and this was included in a recent biography on Nobel. In Sweden.
[46]J. S. Rowlinson, *Sir James Dewar, 1842-1923: A Ruthless Chemist (Science, Technology and Culture, 1700-1945)* (Abingdon: Routledge, 2012), p. 62.
[47]As a personal note, in the author's 2012 article, using indirect evidence, it was proposed that aniline was first to be used in Ballistite, prior to diphenylamine, which was previously indicated by one historian as the first to be introduced in Ballistite in the German July 1889 patent. The author's recent discovery of this visit is direct proof for the estimation, Bergman, 'Alfred Nobel, Aniline and Diphenylamine', pp. 64-67.
[48]Alfred Nobel, 'Celluloidal Explosive and Process of Making the Same', US Patent No. 456,508, 21 July 1889 (first filed on 22 March 1889).

even criticised the use of camphor, thus repeating Abel and Dewar's criticism.[49] When cross-examined in the 1894 trial, Nobel said that he had removed camphor due to the demands of British officials and those of other governments.[50] Thus, Abel and Dewar were not the only ones to criticise camphor, and this adds scientific credibility to their judgment.

Both had also claimed that Ballistite was more likely to chemically decompose, compared to Cordite when stored at elevated temperatures, although the exact test date was not found. Nobel did add a chemical stabiliser, officially diphenylamine, and changed the production process significantly in his July 1889 German patent. More changes in his 20 July 20 1889 application to update his 1888 Italian patent were made in both the process and in the formulations. Here he continued changing the initial mixing steps and the recommended ratios of new ingredients, while making the patent an almost precise and detailed manufacturing procedure, because he was due to sign a production contract with the Italian government within a month. In contrast to the German patent issued on the same month of July 1889, he allowed similar stabilisers to diphenylamine, and the recommended stabiliser percentage was a little lower.[51]

The British Committee was empowered to modify and improve the candidates' samples when it was appointed in 1888. In addition, from 1883, government employees were allowed to submit patents in their own names.[52] These likely facilitated the improvements of Ballistite thus bringing about the Cordite patent. By late March 1889 Abel and Dewar had already prepared and tested their initial samples of Cordite, without camphor, and with a different mixing process, and with an extrusion step, that produced cords – hence the name Cordite. These changes had already appeared in the April 1889 first provisional patent. Soon after, on 22 July 1889, they submitted another provisional patent where they changed the soluble nitrocellulose required by Ballistite to a non-soluble type.[53] On the same day, they submitted a second provisional patent, describing details of the technical side of manufacturing. Here, joining Abel and Dewar as the applicants, was Dr William Anderson, the Head of Government Ordnance factories.[54]

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[49]Alfred Nobel, *'Verfahren zur Darstellung von zu Schiefspulver geeigneter Sprenggelatine'*, German patent No. 51471, approved July 3, 1889.
[50]John Williams, *The History of Explosives,* p. 313.
[51]Bergman, 'Alfred Nobel, Aniline and Diphenylamine', pp. 63-66.
[52]Mauskopf, 'Nobel's Explosives', p. 124.
[53]Frederic A. Abel and James Dewar, 'An Improvement in the Manufacture of Explosives', English Patent No. 11664, 22 July 1889 (Provisional Specification).
[54]Frederic A. Abel, William Anderson, and James Dewar, 'Process and Apparatus for of the Manufacture of Explosives in the Form of Wires or Rods and for Forming the

Nobel soon learned about Cordite but was assured that Ballistite was still being considered. By August 1889, the two sides split, due to disagreements over the patenting of Cordite abroad and on business rights.[55]

It would be fair to say that Cordite and Ballistite patents, were being updated and corrected by the two sides and in parallel until July-August 1889, each becoming more suitable for manufacture and use. But Nobel, contrary to his claim in the 1894 trial that his 1888 Ballistite patent was a master patent, was actually demonstrating through his various technological corrections of mid-1889 that it was deficient in key areas.

The decision to patent Cordite in early 1889, was technologically driven with any profit motives, if they existed, hidden.

The Stated Technological Reasons for Cordite

The first official reason given for the creation of Cordite was objection to the inclusion of camphor. It was openly stated in the provisional patent of 2 April 1889 that Abel and Dewar claimed to have developed Cordite by modifying Nobel's 1875 British patent for Blasting Gelatine. Although the 2 April 1889 patent was withheld from the public until 1892, the same camphor criticism was found in the Swiss patent of 25 June 1889 so Nobel was probably aware of it. They criticised the addition of volatile camphor to Blasting Gelatine to make it a propellant (meaning Ballistite), and wrote that in place of it, they had added non-volatile hydrocarbons, at first tannin and later petroleum jelly. Here, they seem to have taken advantage of Nobel's claim in his 1888 Ballistite patent that Ballistite resembles Blasting Gelatine, with new substances added (as camphor) to obtain Ballistite.[56] So, their criticism may have also implied that Nobel wrongly changed Blasting Gelatine, while they were making significant changes. The 2 April 1889 patent stated that:

> It has been proposed to add to the ingredients of blasting gelatine bodies of an inert kind, such as camphor, in order to lessen the rapidity of the combustion, and thus render the explosive available for propulsive purposes, but, if such inert matter added is of volatile character or otherwise liable to change in quantity or condition, the quality of the explosive of which it forms a part is not sufficiently permanent to be relied on for storage or use. Our invention relates to means of treating blasting gelatine, whether it be simple or compounded with

same into Cartridges', English Patent No. 11667, 22 July 1889 (Provisional Specification).

[55]Mauskopf, 'Nobel's Explosives', p. 125.

[56]Alfred Nobel, Improvements in the Manufacture of Explosives, English Patent No. 1471, 28 December 1888, Complete Specification).

substances which are sometimes added to it such as nitrates of hydrocarbons of a non-volatile character.[57]

The second reason can be found in Abel's 6 April 1889 report to the Committee, which was made several days after his 2 April 1889 submission to the War Office of his initial Cordite patent. He noted that Nobel was in the process of updating his Ballistite patents.[58] He noted that the planned changes were a product of the Committee's advice, when Nobel's propellant was tested in Britain. It would have become awkward for Britain to be obliged to pay royalties on Nobel's improved Ballistite after he had been helped by British scientists. Abel's argument may also have been intended convince the government to adopt Cordite. One of Nobel's updated British patents appears on 14 March 1889, proposing different solvents in the pre-mixing process for making a form of Ballistite for use in mines. This may have been brought to Abel's knowledge. Note that Nobel continued updating the 1888 patent, with another appearing in Britain on 5 June 1889, cancelling the former patent's required use of solvents in the pre-mixing of nitroglycerine and nitrocellulose. [59]

Cordite Development and Differences with Ballistite

The initial Cordite provisional patent of April 1889 stated that the Cordite mixing process and basic ingredients followed Nobel's Blasting Gelatine patent of 1875 in Britain, which basically contained nitroglycerine and soluble nitrocellulose as in Ballistite. Abel himself took out a patent in the 1860s that mixed nitroglycerine and nitrocellulose to obtain an explosive. Besides the legal advantage of not adopting the Ballistite mixing, both may have also resorted to the Gelatine mixing since Ballistite mixing was new and unconventional. In the Ballistite mixing stage, a mixture of nitroglycerine (liquid), nitrocellulose (a fluffy fibre), and the waxy camphor was put between two hot rollers at some 80°C.[60] After a few minutes, a corny, plastic-like, hard and brittle 'carpet' came out of the rollers, to be cut later into small flakes, ribbons, or left as sheets. The mixture on the rollers had a tendency to catch fire. An accident took place at Nobel's Torino plant in early 1890 during production of hundreds of tons for the Italian government, and stopped production there for several months, it may have resulted from a fire of the carpet on the hot rollers.[61] In the Cordite mixing process, as in Blasting Gelatine, nitrocellulose and nitroglycerine were first mixed with organic solvents such as acetone, to provide a safe way to process

[57]Frederic A. Abel and James Dewar, 'An Improvement in the Manufacture of Explosives for Ammunition', English Patent No.5614, 2 April 1889 (Provisional Specification).
[58]John Williams, *The History of Explosives,* p. 248.
[59]Schuck and Sohlman, The *Life of Alfred Nobel*, pp. 273- 274.
[60]Alfred Nobel, English patent 1471 (Complete Specification 28 December 1888).
[61]Bergman, 'Nobel's Russian Connection', p. 57.

the jelly or dough, which was pressed in the next stage by extrusion - another important difference to Ballistite. After extrusion and drying, the extruded cordite rods were collected in bundles or cut into tiny cylinders and loaded into cartridges. At the turn of the century, Germany adopted a similar process to Cordite for its naval guns.[62]

Having relied on Blasting Gelatine, the Committee was concerned on infringing the 1875 patent. In late 1889, it was assured officially that Britain would not have to pay royalties for the patent as it was due to expire at the end of 1889. As a renewal condition, Nobel would have to agree to no royalties when used by Britain. On the other hand, the Committee was confident that Cordite did not infringe the Ballistite patent.

The Cordite Profit Motive

As discussed earlier the Government requirement for the Committee to furnish a British military smokeless propellant, was genuine. The need was expected to be fulfilled quickly as other major European powers were already making headway in replacing black powder with smokeless propellant. Having much less experience with smokeless propellants, Abel and Dewar first relied on Ballistite but soon became sceptical because of its long-term stability due to the use of camphor. This emphasis on camphor might seem to have been an excuse for their own making and patenting Cordite, but their observation was scientifically valid, and was made openly. The move to upgrade Ballistite and create Cordite, was almost a natural imperative, given their pressing task and scientific ability. They not only removed camphor but created a more advanced and safer manufacturing process. This move to Cordite, at a time of high-level government expectations and known problems with Ballistite, must have been the primary motive. Abel and Dewar's aim for profits was likely to have been more opportunistic in nature, given Abel's previous pattern of work. Abel and Dewar were not expecting profits for themselves in Britain, to which, as official employees they were not entitled. The profits abroad, although promising, were a rather far-away expectation due to competition with Nobel. It was not like the immediate reward that Abel had received for his late 1860s Guncotton patent.

Conclusion

The problems with Ballistite and high level government expectation for a British smokeless propellant were the primary motives for the development of Cordite, and Abel and Dewar's arguments for the technical superiority of Cordite were valid. Any profit seeking on their part was opportunistic, and secondary to their meeting the national defence requirement.

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[62] Yoel Bergman, *Development and Production of Smokeless Military Propellants in France,* p. 168.

Abel and Dewar's decisions to proceed with Cordite, and with extrusion playing a major role were both successful with Cordite's ingredients, shapes and manufacturing process differences to those of Ballistite making Nobel's claim of patent infringement at best questionable.