AWARDING BODY: MIDDLESEX UNIVERSITY

COLLABORATING ESTABLISHMENT: MINISTRY OF DEFENCE PATTERN ROOM, NOTTINGHAM

THESIS

THE DEVELOPMENT OF THE ROYAL SMALL ARMS FACTORY (ENFIELD LOCK) AND ITS INFLUENCE UPON MASS PRODUCTION TECHNOLOGY AND PRODUCT DESIGN C1820-C1880

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DECEMBER 1996

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ACKNOWLEDGEMENTS

While there are many people and institutions who have contributed both consciously and unconsciously to the research for this thesis, I should like to pay a special tribute to Herbert Woodend, MBE. and his helpful and enthusiastic staff at the Ministry of Defence Pattern Room, Nottingham. Through the ongoing commitment and dedication of the Pattern Room team to collecting, displaying and recording both documents and artefacts, the life of the researcher has been made considerably easier. In my quest to discover samples of 19th century machine tools I was privileged to be allowed to examine an original Ames gun stock lathe by Michael Wright, Curator of Machine and Hand Tools, Science Museum, London. Likewise I am indebted to Brian Patterson, Curator & Keeper of Historic Boats, Portsmouth Naval Base Property Trust for demonstrating some early examples of Maudslay block making machines. I am also grateful for the help received from the staff of the following establishments:- House of Lords Record Office, Westminster, London; Public Record Office, Kew, Surrey; British Library, Holborn, London; Royal Armouries, London; American Precision Museum, Windsor, Vermont, USA and the Birmingham Gun Barrel Proof House, Birmingham.

I would like to take this opportunity to thank particularly the following gun making personnel for allowing me to take them away from their successful commercial enterprises to demonstrate techniques and answer questions:- Roger Mitchell of Holland & Holland, London; Piers Crump of John Rigby & Co., London; Roger Hale of Parker Hale Ltd., Birmingham and Bob Turner of Turner Richards Gunmakers, Bromsgrove, Worcestershire. Also I am indebted to Ray Tuthill, the Honorary Treasurer of the Royal Small Arms Factory Apprentices Association, for putting me in touch with many skilled tool room personnel and fitters who have added much to the writer's knowledge and understanding of mechanical manufacturing techniques and processes.

I should like to thank my director of studies, Professor Tim Putnam and my supervisors, Dr. Keith Burgess and Dr. Roger Whitaker, for their guidance, help and advice. Finally I owe a great debt of gratitude to my wife and family, who at times appeared to have sacrificed as much as the writer in the preparation and construction of this document. Without their love and support this thesis could not have been completed.

Although information and advice has been freely given by many generous people which has contributed greatly to the formulation of this thesis, it should be clearly understood that the writer takes full responsibility for any inaccuracies or errors of interpretation.

ABSTRACT

Through a study of the Royal Small Arms Factory (Enfield Lock) and its influence upon product design and development, we examine an apparent anomaly. While accepting that Britain was the seat of the industrial revolution, several historians have claimed that American engineers held the technological advantage in the manufacture of small arms in the first half of the 19th century. Accounts of this disparity in the main have sought economic answers but this thesis examines technological change in relation to the weapons procurement system for the British armed forces operated by the Board of Ordnance. Attention is focussed upon the political interplay between the public and private sectors of the gun trade, which was particularly influential in delaying the progress of the British military small arms industry towards the standardisation of weapons through a mechanised system of manufacture. As a result, reliance by the private sector upon traditional labour intensive methods of production remained perhaps longer than would otherwise have been the case.

In addressing these issues it is argued that Britain's seeming hesitancy in maintaining her earlier rate of technological progress was the result of a veritable cocktail of events, with several factors at play. The investigation draws on primary documents and secondary accounts complemented by interviews with representatives of established small arms manufacturers, skilled craftsmen, weapons and machine tool experts and an examination of relevant artefacts, the results of which have cast doubt on some aspects of received interpretations of early part interchangeability.

This study re-appraises the important role and character of one of the most influential and controversial "Ordnance" figures of the period, George Lovell. It sets the Board of Ordnance method of weapon procurement against the methods of other purchasing agencies, notably the East India Company. The results of the inquiry indicate that Britain's seeming technological pause in the field of small arms manufacture was more due to political influence and the administrative structures than to a lack of technical expertise on the part of its engineers, entrepreneurs and craftsmen.

INTRODUCTION

Reading the many standard works which attempt to trace the history and development of the manufacture of small arms it would be a simple matter to gain the impression that the entrepreneurship, manufacturing technology and inventiveness which arose out of the industrial revolution had stagnated in Britain by the early part of the 19th century. Commentators such as Ames and Rosenberg have suggested that "Americans clearly led the British in the adoption of many machine methods of production", which seems to imply that somehow the manufacturing technology transferred to America early in the century where it grew and flourished. .1. While there is undeniable evidence to show that American manufacturers and entrepreneurs had embraced and developed this new technology, initially concentrating their efforts on solving the difficult problems which were associated with the methods and procedures of standardised manufacturing in the production of small arms, the main thrust of this thesis will be to examine the basis for Ames and Rosenberg's assertion that America was either moving faster or Britain's early technological progress had paused. It is intended to discover why it was that engineers and industrialists in Britain had apparently not followed a more rigorous approach to producing weapons by machinery after having the technological initiative of the industrial revolution, seeming to prefer traditional labour intensive methods of manufacture. We will also attempt to discover how Government reacted to this apparent loss of technical advantage. In addressing these issues, the following question will be asked:- were there people in Britain with the requisite vision and engineering skills to have taken forward the manufacturing technology into the area of small arms production? If it is found that such people existed, then it will be necessary to ascertain what were the factors which apparently held them back. For example, was there the possibility that in Britain, little demand for small arms existed at the time?

Although the investigation will concentrate on issues this side of the Atlantic, the opportunity will be taken to discover through comparison with the work of American scholars, parallels with the reasons why small arms manufacturing technology developed within the United States national armouries, particularly with the progression towards production by the system of interchangeable parts. This will be contrasted with what seemingly delayed progress towards a mechanised system of manufacture for the production of military firearms in Britain.

The action of putting these issues under the microscope for the purpose of investigation is not to make claims for British or American engineering skills by trying to decide in which country a product or manufacturing process was developed or invented. Claims are often made on the basis of commercialism when kudos can be gained for a country by suggesting that ideas or processes invented or developed by a particular individual or group was an "industrial first". Pursuing an investigation into such claims would not be helpful to the inquiry in hand and would only prove distracting to the research. For example, it can be argued that Marconi did not invent wireless, as many people like Hertz, Lodge and Faraday had worked for years before him on the development of the technology which made the medium possible. Nevertheless, what Marconi did was to exploit the available embryonic technology and develop a system which required a commercially viable product to promote it, in this case, the wireless transmitter and receiver. Similarly, the manufacturing system of interchangeable parts did not occur from a single stroke of inventive genius but had many different contributors. Of course, like wireless, the system required a commercially viable product to promote it, initially this was the small arm. The important issue for our investigation is, what were the factors which encouraged, or in the case of the British small arms industry, delayed the mechanised manufacture of military small arms?

On the path to mechanised military small arms manufacture, the relationship between George Lovell (Storekeeper at the Enfield small arms factory), and the private "Ordnance" contractors will be addressed. The period of particular interest is after Lovell's promotion to Inspector of Small Arms in 1840, reporting directly to the Master General of Ordnance. Here we are provided with some of the most important clues which help to explain why the British small arms industry during the first half of the 19th century took a quite different approach to the production of military weapons in comparison to that of the United States of America. While the evidence shows that the British small arms industry retained labour intensive manufacturing much longer than America, being slow to adopt mechanised methods of production, particularly in the area of locks and stocks, the greatest drawback to technological progress came from the method of

"Ordnance" arms procurement.

By making a detailed examination of the evidence taken from Government Select Committee Reports and official "Ordnance" correspondence, it has been possible to assemble a comprehensive picture of the "Ordnance" contract system of arms procurement. This has helped to reinforce the conclusion that the "Ordnance" method of weapon procurement was one of the more crucial elements in a number of influencing factors which led to delaying the introduction of machine tools for the mass production of small arms in Britain.

In examining George Lovell's multi-faceted role in small arms manufacture and weapon development it will become clear that he was one of the most influential and controversial figures within the British small arms industry. Although Lovell has been acknowledged by writers and arms experts like De Witt Bailey for his innovation and weapon design skill, this is the first study in which his dealings with the "Ordnance" private contractors has been fully assessed. In moving towards an improved product standard, Lovell was responsible for increasing the strictness of the "Ordnance" "view" (quality control and inspection). By analysing the consequences of these stricter inspection standards it will be shown how they had a marked effect upon the British small arms industry, causing considerable problems and hardship for the private sector. The episode allows a closer study of a complex game played by the Inspector of Small Arms in his quest to manoeuvre a reluctant "Ordnance" into taking control of weapon manufacture. By contrasting the "Ordnance" methods of view with the strategy employed by officers of the East India Company when procuring arms from the same private contractors as the British Government, we question the criteria of the "Ordnance" weapon inspection system, especially the insistence on high levels of finish, which to a certain extent can be seen as a hang-over from the traditional labour intensive methods and artistic embellishments employed in the manufacture of sporting guns. Such weapons were often crafted individually, which meant they were aimed at a quite different customer base than the mass markets of the military.

This comparison puts in perspective the continuing criticism of "Ordnance" by the private contractors throughout the first half of the 19th century, much of which became personalised against Lovell. Conversely criticisms were levelled against the independent gun trade by "Ordnance" who accused the contractors of deliberately setting out to extract the highest possible prices for weapons and falling behind in their contractual obligations. The reasons for these beliefs will be examined and it will be suggested that "Ordnance" could have considered other methods of obtaining arms supplies from the private sector. To counterbalance the "Ordnance" accusations against the contractors, an examination of the "Ordnance" system of open tendering will be taken, which had high standards for low prices within its weapon procurement criteria. After the new system of open tendering was introduced in the late 1840s it will be shown how its effect upon the private sector further increased weapon supply problems.

Examining how George Lovell dealt with "bottle necks" in the weapon manufacturing process created by the scarce supply of seasoned walnut allows a new insight not only into the way production problems were solved but, perhaps more importantly, in the way Lovell thought and behaved in the political arena. Through this episode we are permitted a glimpse of the different pressures which were at play, both bureaucratic and political, which helped to delay the progresses of innovative techniques in the British small arms industry. By examining the method employed to increase the supply of walnut for use in the manufacture of military gun stocks, we are allowed through a serious, although somewhat naive miscalculation by Lovell's son, the Assistant Inspector of Small Arms, to witness how this led indirectly to the installation of a new wood desiccating process chamber at Enfield Lock.

Correspondence between the Master General of Ordnance and the Superintendent of the Royal Small Arms Factory, Enfield allows for the first time a vivid insight into the Master General's knowledge of the processes involved in the development and manufacture of small arms. This information will be analysed in the context of "Ordnance" arms procurement at the time of the Crimean War. The opportunity will also be taken to examine the impact of this particular war upon the British small arms industry, which by the middle of the century had reached a critical stage in its development.

Innovation and manufacture

In assessing the role of "Ordnance" weapon procurement in the emergence of mass production technology, the aim will be to discover the influencing factors affecting the manufacture of machine produced small arms. In particular we will ask whether considerations of weapon manufacture were purely those of military performance, or if cost and engineering efficiency took precedence. These questions will be pursued in the study of how new weapons were designed, tested and selected for the armed forces.

In modern methods of machine production it is known that the product designer will endeavour to use his knowledge of the manufacturing processes, consulting with other members of the design and production teams. This ensures that the most cost effective and efficient means of factory output is achieved. The approach is adopted to make sure that the product can easily be accommodated within the current production technology rather than having the costly problem of adapting machinery or increasing the labour content to facilitate manufacture. For example, paying particular attention to such aspects as machine cycle times, achievable component shape, material wastage and ease of assembly can all have a beneficial effect on a product's profitability. Designing a product with regard to available production processes can often have advantages for quality by reducing the complexity of inspection. The opportunity will be taken to examine the methods of early weapon selection to see how widely the concept of integrating design with ease of manufacture was understood or even acknowledged. From these discoveries it will be shown that although there were some engineers who understood and appreciated the benefits of designing a product for ease of manufacture, the "Ordnance" procurement system and the method of new weapon selection, was not conducive to incorporating such advantages within the manufacturing process. In the case of the private gun trade, most were small firms using labour intensive methods of manufacture. The scale and short nature of military contracts held little advantage for such enterprises. New small arms selection was normally by open competition, when weapon performance and price were the criteria for acceptance, not ease of manufacture. These aspects will be fully discussed within the context of the thesis and examples of military weapon trials will be investigated to discover what were the specific priorities governing acceptance.

Intertwined with all the various strands of technology, development, innovation and diffusion is the use of the artisan's skills and how they may have been affected, changed, improved or diminished by the advance of machine intensive methods of production. These aspects will be addressed within the overall framework of the thesis, firstly to understand what if any were the effects of increased amounts of mechanisation upon the workforce and secondly to discover if changes occurred in the organisational and reporting structure due to the growth in machine tool numbers.

When looking retrospectively from the twentieth century it can be seen that the Royal Small Arms Factory (RSAF) played a prominent role in the field of small arms development. A considerable number of well preserved artefacts remain to support this observation. Examples can be seen, though not always examined, in collections of several museums and within the Pattern Room of the Ministry of Defence, Nottingham. These help to further our knowledge.

With a view to learning more about the integration of artisan skills with the coming of the new machine technology, negotiations were undertaken with the Ministry of Defence (MOD), Nottingham from which it became possible to examine in detail a small number of gun lock tumblers removed from complete weapons within the prodigious collection held in the Pattern Room. The tumblers were taken from sample small arms which were selected by the Custodian who ensured that the parts under examination were manufactured before and after the installation of American machine tools at Enfield Lock in circa 1856. In this way it was hoped that the tumblers, an intricate part of the lock to produce, would provide evidence of early manufacturing techniques. While the number of samples was limited to three, it was possible to detect variations between the early and later examples. With the cooperation of an MOD weapons expert and two time-served retired engineers from the Royal Small Arms Factory, Enfield Lock, a physical examination of gun lock tumblers was undertaken to look for evidence of hand finishing and to generally interpret the markings left on the metal.

Robert Gordon in the United States has carried out an in depth physical study of how early and mid 19th century tumblers were manufactured. From his study he has been able to conclude from the different tool marks found on this key component together with an analytical examination of the documentary evidence from the Springfield National Armoury, that the hand skills of artisans, rather than becoming diminished with the introduction of machine tools as suggested by some contemporary writers like Felicia Deyrup, actually remained for much longer than had previously been thought. .2. The evidence obtained from examining the British tumblers will be compared with Gordon's work to see if the conclusions he reaches in relation to machine finishing and hand labour can be supported. Through the independent examination of the Nottingham tumblers and discussions with the time-served engineers, it will be shown that a better understanding has been gained of the production techniques in operation at the time the parts were manufactured.

The expert opinions offered by these men has helped to account for differences observed between the samples. These and other observations when analysed in the context of British 19th century inspection criteria, has called into question the strictness of "Ordnance" viewing standards. The physical exercise of examining these components has caused the writer to reassess what actually passed for mid 19th century weapon part interchangeability, rather than accept at face value the several written accounts. By commentators loosely using the term interchangeability, without trying to discover if there were or were not acceptable tolerance spreads within which the parts could still be effectively used, a gap has been left in our knowledge.

Once "Ordnance" accepted the necessity of mechanising military weapon manufacture by the middle of the century and the new American machinery was seen to be working successfully at

Enfield, the RSAF became a model production facility acting as an example for others to follow. This period will be examined for evidence of technology transfer which embraces both inward and outward technological diffusion; in modern parlance "spin in" and "spin out".

Much of what has been written about the development of the RSAF has tended to concentrate on the period post 1850 and the dramatic changes to production caused by the installation of the American machine tools. Therefore, in concluding the thesis it will be necessary to assess the factors which determined the direction and route taken by the RSAF, from a position of relative obscurity during the early part of the century, to one of high profile, achieving a reputation for technical excellence by the late 1850s in the world of small arms manufacture. However, to understand how the RSAF underwent this major transformation and advanced to a position of considerable eminence, it will be necessary to probe the mainly neglected first half of the century to understand the key determining factors.

<u>Establishing the armoury at Enfield Lock</u>

At this juncture in the introduction it is intended to set the scene for the thesis by firstly familiarising the reader with the early beginnings of the Royal Small Arms Factory at Enfield Lock through a "thumb-nail" history, allowing a brief insight into the way the site developed during the first half of the century. This will be accompanied with an outline of the issues surrounding the small arms industry which were occurring as the century progressed. It is believed that this approach will quickly establish in the reader's mind the relationship between the various themes under discussion in the following chapters and the periods to which they relate.

The construction of the "Ordnance" small arms factory beside the River Lea at Enfield Lock, on the Essex and Middlesex borders, came about through a British Government initiative. Action to proceed with construction had been provoked by what the Board of Ordnance regarded as the failure of the private gun trade to provide sufficient quantities of weapons for the Army during the period of the Napoleonic Wars. By 1816 the factory and houses for the workmen and their families had been completed. Also during this year the barrel branch from the Royal Manufactory at Lewisham was incorporated into the site as water power for the south London armoury began to fail. The lock and finishing sections from Lewisham were integrated later, adding to the site's gradual expansion. However, it was not until some forty years of relative peace, after commencement of the Crimean War, that major building and equipping of the Royal Small Arms Factory (as it was later to become known) took place, providing the capability of producing large quantities of weapons by standardised methods of machine manufacture. Up until the middle of the century the factory acted largely as a research and development establishment, a repair facility and a small weapon assembly and modification shop. Because of the expertise of the workforce, the establishment was also used to monitor the price and quality of finished parts and weapons manufactured by the private contractors for "Ordnance".

Despite the initiative taken by Government to control and secure regular supplies of military small arms by constructing the factory at Enfield Lock, it was over four decades before the armed forces were able to derive real benefit of quality arms in quantity from this plant. The circumstances which were responsible for this somewhat ironic situation provide an interesting study, and form a major part of this thesis. Here the reasons will be discussed why the private sector was still producing and providing the bulk of military small arms up until circa 1857. We will examine the paths of both the private and public sectors of the British military gun trade during this period and show how the industry had to go through a prolonged and painful evolution before it could be claimed that weapons were manufactured in reasonable quantities to a consistent and reliable standard.

Reviewing small arms provision at mid-century

In October 1853, Mr (later Sir) John Anderson, the chief engineer of the Royal Arsenal at Woolwich, was sent to Enfield and instructed to find out whether the factory was capable of manufacturing bayonets by machinery. Following his visit Anderson issued a report to which the official response of "Ordnance" was to appoint a Committee to consider the whole question of small arms provision for Her Majesty's Service. Lieutenant Colonel Alexander Tulloh, Royal Artillery, Inspector of the Royal Carriage Factory at Woolwich, and Colonel James Archibald Chalmer, R.A., Inspector of Artillery, reported to the Committee making the following observations:-

> It appears that the system hitherto adopted to procure small arms is so heterogeneous in its character, that it could not fail to produce considerable difficulties. The Government establishment at Enfield Lock is comparatively small and of a mixed nature, some parts of the work being performed by the establishment, some by contractors; many of the lathes and tools are the property of the workmen; others belonging to the establishment. The men possessing lathes hire them out to other men.
>
> The establishment at Enfield Lock being small, and forming part of the heterogeneous system, is unable to hold that check or control over the contractors to prevent exorbitant demands and serious delays.
>
> The principal part of the gun trade upon which the Government mainly depends for supply in case of emergency, is carried on in Birmingham and London, by men working by hand in wretched cellars and garrets, and great evil arises from the slowness of manufacture. .3.

It will be gathered from these findings that the Committee had reinforced the image, already held by "Ordnance", that the small arms industry in Britain was in rather a perilous state. This would appear especially true if one considers the imperial role of Britain in the 19th century with the need to police her far flung Empire. Furthermore, for a nation which had been at the heart of the industrial revolution it must have been extremely embarrassing for Government to witness senior "Ordnance" officers being forced to purchase quantities of arms from continental manufacturers in times of conflict. Having to go abroad to find ways of bridging the gaps brought about by recurring delays to small arms contracts was clearly an unsatisfactory state of affairs for a proud nation.

Further scorn was heaped upon the private gun trade when Sir Thomas Hastings, the Ordnance Principal Storekeeper, read out in evidence to the Committee some of the written excuses given by contractors for delays. These were:- strikes amongst the workmen, accident to machinery, illness of a skilled artisan and difficulty in procuring coal. It would seem there was little sympathy with the contractor's reasons as Lord Raglan, the Master General of Ordnance, and Sir Thomas Hastings had already formed the view that "Ordnance" should take control of small arms manufacture when they stated:-

> ... they had been guided in their opinion partly by the report of the Commissioners who, during the last year, visited the manufactories of the United States, and partly from communications with Mr Anderson and other persons conversant with machinery. .4.

Reading the report, and considering the evidence from the Committee's point of view, it would be difficult to see how they could have reached any other conclusion than that the Board of Ordnance should assume overall responsibility for military small arms manufacture. During the previous three years "Ordnance" had complained of worsening arms deliveries and the commencement of war in the Crimea had increased pressure for a radical review of procurement. .5. Again, it was the sad experience of the British armed forces to be deprived of sufficient quantities of reliable weapons in time of war and once more "Ordnance" had to turn to the independent gun trade for supplies.

The private sector, for reasons which will be explained later in the thesis, had not modernised its method of manufacture and did not do so until well into the second half of the century. Up until then it still relied heavily on traditional manual skills particularly in the production of locks and stocks. Paradoxically, some elements of barrel manufacture had been mechanised quite early in the century. This was found necessary due to the relatively high reject rate at proof, caused in the main by poor quality iron. However, it was not until the independent gun trade's hand had been forced by competition from the new Government factory at Enfield Lock, that a group of private contractors decided to set up the Birmingham Small Arms Company (BSA). Further pressure for radical change was heaped upon the private sector when it became "Ordnance" policy to place contracts only for weapons manufactured with interchangeable parts.

However, to improve our understanding of the British military gun trade in the middle of the century it will be necessary to examine the events and influencing factors which occurred during the first part.

The influence of George Lovell

George Lovell was appointed Storekeeper at Enfield Lock on 1st April 1816. The date coincided with the barrel branch being moved from Lewisham. Most students of the history of the RSAF agree that it was Lovell more than any other individual who, with his expertise and dedication, laid the foundations and set the bench marks for quality and reliability which were to become synonymous with the RSAF in later years.

Lovell was determined to improve the tolerance standards of weapons and piece parts delivered to "Ordnance" by the private contractors. In 1833, equipped with a new micrometer he was able to ascertain that the instruments used for measuring the bores of barrels varied between 0.752 and 0.760 of an inch. He therefore set the standard at 0.754 of an inch, a measurement which would be adhered to in the future. .6. From 20th century experience it is known that increased levels of accuracy will call for greater standards of skill and improved manufacturing techniques if high rejection rates are to be avoided. Refinements of this sort can lead to a short term decrease in manufacturing output, accounting for a reduction in profit margins. Therefore, it is understandable that Lovell's demands for tolerances to a thousandth of an inch brought considerable criticism from the private "Ordnance" contractors. One anonymous observer, unhappy with the new imposed standards, called Lovell "a cabinet or bedstead maker by trade". Going on, this figure criticized the strictness imposed by the "Ordnance" viewers which led "to a litigious vexatious nicety of gauging, and finished appearance unknown in the highest finished fowling pieces". He described as absurd "the principle of exact jigging, gauging, moulding and other fantastic accuracies". .7. The consequence of "Ordnance" imposing strict inspection and quality standards form part of the complex character of the British small arms industry and illustrate the somewhat precarious nature of the military gun trade. These issues will be fully addressed later in the thesis.

Lovell's problems did not subside after his appointment to Inspector of Small Arms, the most influential position in all aspects of military weapon design, manufacture, and procurement below that of the Master General of Ordnance. If anything, the personal attacks increased and considerable controversy was to surround his later years. The reasons for this will be addressed in chapters five and six.

"Ordnance" dilemma

It is clear from the many written accounts of the British gun trade in the period to the middle of the century that production was essentially fragmented, being split mainly between the London and Birmingham private gunmakers. The industry suffered from the lack of demand for arms after 1815 when military conflict with France ceased. Government's apparent reluctance to initiate a policy of major intervention into the arms industry was primarily due to the private gun trade's successful lobby of Parliament and in part due to the strong influence of the Duke of Wellington who, as Commander in Chief of the Army, believed that the quality of arms themselves needed no improvement. It was only the degree and extent of the troop's instruction in their use that needed to be improved. .8. In addition, the contract system operated by the Board of Ordnance, with its poor technical support and the withholding of gauges and patterns to the contractors, had helped create supply and price difficulties for military weapons, deepening the impression that the private sector was incapable of meeting the reasonable demands of its customer. These were just some of the issues facing both "Ordnance" and the private gun trade as the middle of the century approached.

Delaying change

By 1854 the Board of Ordnance had received reports both from the Commission to America led by Lt. Colonel Burn in that year and from Joseph Whitworth in the previous year, detailing the reality that the government armouries in the United States were employing large amounts of machinery in the manufacture of rifles. The level of mechanisation was reported as being particularly advanced in the operations of forming, shaping, and fitting out gun stocks, formerly considered a highly labour intensive part of the gun manufacturing process. It was not as if the American Government had kept the technology a secret, for machinery capable of making 130 to 160 gun stocks per day had been offered to the Board of Ordnance by an American agent Samuel Cox as early as 1841. As is well known, the technology for manufacturing large scale irregular and complex shapes in wood had existed in Britain since the early part of the century. Less than one hundred miles from Enfield, in the Portsmouth dockyards, the relatively complicated ship's pulley block had been manufactured for the Navy on a sequence of machines invented by Marc Isambard Brunel and built by Henry Maudslay, the eminent London engineer. Maudslay's workshops were located within one hour's travel from Enfield, so it is hard to imagine that "Ordnance" management were ignorant of the available manufacturing technology, especially as it was the Admiralty, another branch of Government, which had been responsible for financing the Portsmouth factory. .9. However, the process seems not to have been adopted in Britain for the purpose of manufacturing gun stocks although there is evidence to suggest that the principles upon which the Portsmouth machinery was based were probably taken up by American machine tool inventors like Blanchard and the ideas incorporated into their own designs, these finding their way back to England later in the century. These aspects of technology transfer will be discussed in a separate chapter.

The Great Exhibition of 1851 in London's Hyde Park allowed a wide body of "Ordnance" experts and private gun contractors as well as members of the public to witness the advances made by American manufacturers and engineers in production technology. Robbins and Lawrence, an American company, sent six U.S. Army rifles for display and demonstration, all manufactured with parts that interchanged. Samuel Colt exhibited his revolvers, which he claimed were made almost entirely by machinery and having parts that were interchangeable. .10. What is interesting about these two American companies employing high levels of machinery in the manufacture of their products was that they were both in the private sector and producing weapons for the United States Government, setting them quite apart from their labour intensive British counterparts. It would therefore seem reasonable to speculate that there must have been compelling reasons for their adopting the approach of investing in high levels of capital equipment, while in the main their British equivalents appear to have resisted mechanisation. For this reluctance to have existed for so long in Britain, would seem to indicate that strong and powerful forces were at play.

The reasons which prompted these transatlantic differences will be addressed in the thesis.

Grasping the nettle

When the second Commission was sent to America in 1854 led by Lt. Colonel Burn R.A, it had been given quite specific instructions to inspect the different gun factories and to purchase such machinery and equipment as found necessary for the proposed new factory at Enfield. This was quite a different approach to that of the Commission of 1853 which included Joseph Whitworth (later Sir) the distinguished engineer. Whitworth did not go to America expressly to view the gun manufacturers as might be implied by reading some accounts of the visit. Initially he went to attend the New York Industrial Exhibition. This would seem to indicate that in less than a year, the procurement of small arms for the British army and navy had reached an extremely critical state. Accompanied by George Wallis, Headmaster of the Birmingham School of Art, Whitworth appears to have taken it upon himself to have altered his itinerary, as it is suggested "...and while there they extended their enquiries by visiting several establishments, among others the Government Arms Factory at Springfield". .11. This observation is further substantiated in Whitworth's evidence to the 1854 Select Committee when he stated "...that he had not been specially directed to inspect the manufactories of fire-arms, and had not therefore given the close attention to the subject which he would have done if he had foreseen the present inquiry". .12.

The introduction to the 1854 Committee on Machinery's 87 page report sets out their terms of reference and provides an insight into some of the circumstances which helped bring about a marked change of direction by "Ordnance". The reasons which were eventually to cause "Ordnance" to take on the responsibility of becoming a major manufacturer of military small arms can be seen from the following extract of the report.

> Owing to the delays constantly recurring in the fulfilment of contracts for arms, the high price demanded by contractors,

> and the inconvenience occasioned to the Service by these causes, the Honourable Board of Ordnance, towards the end of the year 1853, considered it advisable, in order to secure a regular supply of them, to take this branch of manufacture into their own hands, and erect a Government establishment capable of producing muskets in large numbers, and at a moderate price by the introduction of machinery into every part of the manufacturing where it was applicable... Having caused a plan of the building they proposed to erect to be drawn out,... set to work as speedily as possible; and hearing from Mr Whitworth and others that machinery was extensively applied to this branch of manufacture in the United States of America, where, on account of the high price of labour, the whole energy of people is directed to improving and inventing labour-saving machinery, the Honourable Board consider it advisable to send over to that country some of their officers, with a view to obtaining every information in their power connected with the manufacture of arms as there conducted, and with the power of buying such machinery as they might consider would be more productive than that used in England for similar purposes. .13.

The second Commission to America placed contracts for machine tools with Robbins & Lawrence of Windsor, Vermont, and the Ames Manufacturing Company, Chicopee, Massachusetts. This latter company produced machinery for fashioning gun stocks, bedding the barrel, and letting in the lock. The machinery proved to be so efficient and reliable that when writing the history of the Royal Small Arms Factory in circa 1930, G H Roberts, the then Superintendent, proudly wrote:-

> It is interesting to note that several of the woodworking machines supplied by the Ames Co. are still in use today and giving good service, in fact one well known Firm of English machinists recently declared that even today they could not improve upon the American machines in the matter of output etc. .14.

Roberts commented further:-

> As regards Messrs. Robbins & Lawrence machines, a small Horizontal Milling Machine of their make, probably one of the last of the plant supplied by them, has been scrapped within the last year or two, although it has not been worked for some time. .15.

It can be concluded from the report made by the Commission after visiting the U.S. Armoury at Springfield, that their decision to place orders for what must be considered a substantial quantity of machinery was influenced by at least two important factors. One, that a complete gun stock could be made on a sequenced operation of forming machinery and two, the ability of a workman to randomly assemble arms from parts taken from weapons which had been manufactured over a ten year period. The Commission was also successful in arranging for James H Burton, former Master Armourer of Harpers Ferry, to be brought to England on a 5 year contract to oversee the installation and the commissioning of the machinery at Enfield Lock. .16.

Enfield comes of age

The years 1855 to 1859 saw the rapid expansion of building at Enfield Lock. Construction work was carried out by the Royal Engineers under the supervision of Captain Thomas Bernard Collison, R.E. During this period the large machine room was completed specifically to house the new machinery, much of which was purchased in America by the 1854 Commission. The plant was designed for an estimated annual production of 130,000 muskets and bayonets. In these early years, although expenditure on land, buildings, machinery, and gas works amounted to £315,000, the success of the plant was such that, according to Roberts, by 1862 this sum together with depreciation of £48,000 was said to have been entirely repaid by the reduced cost of production.

Before 1861 the energy source for the Enfield manufactory had been water taken from the River Lea to drive two 18 foot diameter cast iron water wheels, each having an estimated output of 46 horse power. The design of the drive, which did not incorporate governors, was reported to have made the outputs very irregular. The main function of the water wheels was to run the barrel grinding shop which according to reports continued with this power source until 1887. Remarkably, the traditional grit grindstone remained in use much longer, not being finally discontinued until circa 1926. .17.

In 1852 a new barrel rolling plant was installed and by 1853 Roberts suggests that the factory capacity had been increased to accommodate 50,000 muskets and 3,000 swords per annum. Prior to this, and using only an average of 25 horse power before steam was introduced, it was claimed that the production rate of the Enfield factory had been in the order of 7,000 small arms and 1,500 swords annually. .18. However, Tim Putnam when referring to George Lovell suggests that "the number of complete weapons in his period never approached that figure". .19. This is based on evidence that Enfield took in parts from sub-contractors for setting-up into arms, which would tend to reduce the claim of the overall number of weapons completely manufactured on site.

In the year ending 30th June 1860 the output of rifles alone had increased to 90,707, an average of 1,744 per week, later to go up to 1,900. By the year 1861 1,700 men were employed at the plant and it is recorded that the large machine room was driven by two 40 horse power steam engines with Fairbairn expansion gear, while in the barrel mill a 70 horse power steam engine was employed along with the existing water wheels. .20.

It would therefore seem that one can proclaim with confidence that by the late 1850s the "American system of manufactures" (as it has popularly become known), had truly arrived at Enfield and was seen to be working. The private gun trade had yet to respond to the challenge of producing military weapons with standardised and interchangeable parts by the extensive use of machine tools.

In this introductory chapter a number of themes and issues have been highlighted which will be investigated in individual sections of the thesis. One in particular concerns the role of the Inspector of Small Arms, George Lovell and his relationship with the private gun trade when acting as the interface between them and "Ordnance". As it will be revealed it is Lovell's influence, more than any other individual, which has helped to mould the shape of the future British small arms industry.

While there are issues of standardisation and flexibility arising from the installation of the American machine tools at Enfield Lock, there are also aspects of "Ordnance" weapon selection which need to be evaluated in the context of engineering efficiency. All these points will be discussed and analysed together with the effects, problems and advantages of the new machine technology for both the Board of Ordnance and the British independent gun trade.

Note.

Due to the complexity of the subject under investigation and the many different influencing strands, the individual chapters will address the major issues separately. To assist continuity and to reinforce the debate, the opportunity is taken throughout the thesis to repeat certain important themes, issues and events.

NOTES

.1. Ames, Edward & Rosenberg, Nathan, "The Enfield Arsenal in Theory and History", The Economic Journal, December 1968 pp.841-842

.2. Gordon, Robert B, "Who Turned the Mechanical Ideal into Mechanical Reality?", Technology & Culture, Vol.29, No.4 (October 1988) pp.744-778

.3. Cottesloe, Colonel Lord CB, "Notes on the History of the Royal Small Arms Factory, Enfield Lock", Army Historical Research, Volume 12, (undated, probably c1932), pp.200-201

.4. Report from the Select Committee on Small Arms, House of Commons, May 1854, (184. 251), p.2

.5. Ibid., p.1

.6. Blackmore, Howard L, "Military Gun Manufacturing In London and the Adoption Of Interchangeability", Arms Collecting, Vol.29, No.4 (November 1991) pp.116-118

.7. Ibid., pp.116-118
It is worth noting that George Lovell, the first Storekeeper at the RSAF, should not be confused with Frederick Lovell, his brother, Clerk 1824, or Francis George Lovell, his son, Assistant Inspector of Small Arms 1843. Robert Lovell another son also worked in the industry.
Calling Lovell a "bedstead maker", probably refers to the late 1820s when, to keep the Enfield factory working, Lovell took on all kinds of jobs, including making bedsteads. See Tim Putnam & Dan Weinbren, "A Short History of the Royal Small Arms Factory Enfield", Middlesex University, (1992) p.11

.8. Bailey, De Witt,"George Lovell and The Growth of the RSAF Enfield", paper presented at an MA Day School, Middlesex University, 4th July 1992, p.6

.9. Op.cit., Blackmore, Howard L, pp.117-118

.10. Hubbard, Guy, "Development of Machine Tools in New England," American Machinist, Vol. 60, No. 4, January 24th 1924. p.129

.11. Gilbert, K R, "The Ames Recessing Machine: A Survivor Of The Original Enfield Rifle Machinery", Technology and Culture, Vol.4, Part 2, 1963. pp.207-208. See also Op.cit., G H Roberts, p.C13. Also see J Whitworth & G Wallis, "The Industry of the United States in Machinery, Manufacturers and Useful and Ornamental Arts", 1854.

.12. Op.cit., Select Committee on Small Arms 1954, 2165. 2177

.13. House of Lords Record Office, London.
Report of the Committee on the Machinery of the United States of America, Presented to the House of Commons, in Pursuance of their Address of 10th July, 1855, p.547

.14. Op.cit., Roberts, p.C10

.15. Ibid., Roberts, p.C10

.16. Ibid., Roberts, p.C10

.17. Op.cit., Cottesloe, p.202. Also see Ibid., Roberts, G H, p.C10

.18. Op.cit., Roberts, p.C5

.19. Putnam, Tim & Weinbren, Dan, A Short History of the Royal Small Arms Factory Enfield, Middlesex University, (Enfield, 1992), p.141. See also Roberts, G H, p.C5

.20. Op.cit., Roberts, p.C12

THE GREAT MECHANISATION DEBATE

There has been much debate amongst economic historians and historians of technology regarding the different speed of certain technological developments between Britain and America in the first half of the 19th century. It is agreed by most commentators that Britain at the beginning of the century led the world in innovative manufacturing machinery particularly in the processing of cotton and the sequenced production of mass produced ship's pulley blocks by dedicated machine tools. .1. Somehow, as the century progressed, these early initiatives appear to have been lost to American engineers and entrepreneurs who developed and enhanced the technology of self-acting machine tools and standardisation. The area of manufacture chosen by most leading commentators, and the one which best illustrates how America seemingly gained the initiative over Britain, was in the production of standardised small arms with interchangeable parts. This also includes the development of machine tools upon which these small arms were made.

In general scholars have concentrated on the reasons for America's rapid industrial progress from the start of the century, rather than addressing in a systematic way the many complex issues which influenced Britain's apparent technological slow-down. Some of the popular assumptions imply an air of contest, suggesting that fresh Yankee ingenuity was more in keeping with the visionary advance of the New World, which was leaving the more mature and sedate ways of the old country behind. Although some historians have attempted to explain why

British industry had not seemingly maintained its technological advantage in the area of mechanised production by using such arguments as material shortage and the abundance of cheap labour which suppressed machine growth, they have failed to fully explore the influence and effect upon the indigenous gun trade of a military small arms procurement system operated by the Board of Ordnance and its officers.

To commence the debate it is worth looking at the state of the British small arms industry through the eyes of a mid 19th century observer and from there investigate the various reasons put forward by the more prominent commentators concerning the technological development of small arms manufacture on both sides of the Atlantic. We will concentrate on the reasons which seemingly held the British small arms industry back during the first part of the century, rather than those which gave their American counterparts a technological lead in the field of machine tools and mechanical interchangeability.

<u>The state of the British gun trade</u>

In his presidential address to the Institute of Civil Engineers in January 1868, Charles Hutton Gregory, speaking of the year 1852, stated that:-

> ...prior to this time the construction of firearms was really carried out by small manufacturers, who each made only one separate part, one for locks, one for barrels, one for bayonets etc, the gunmaker being, in fact, little more than a setter up; and the Government after obtaining by contract the separate parts of the muskets, excepting barrels and some small parts, from separate manufacturers put them together at their own works at Enfield". .2.

Research has confirmed the picture of the gun trade prior to the mid 1850s painted by Gregory but further investigation suggests that, as a result of a poorly operated Government arms procurement system, the private sector suffered from under-investment in capital equipment. It will be shown later in the thesis that the private gun trade, which up until the middle of the century had produced the lion's share of military small arms, had been successful in preventing a major Government intervention into its sector by maintaining pressure upon Parliament. There is also evidence to suggest that, as late as the latter part of the 1840's (at least on the surface), "Ordnance", through the office of the Inspector of Small Arms, was having second thoughts about its original intention of becoming a major small arms manufacturer. That is not to say "Ordnance" lacked the necessary skills to perform such a task, as evidence confirms they were suitably experienced and equipped. Previously in 1787 "Ordnance" had taken over the running of the Waltham Abbey Gunpowder Mills to secure supplies of powder for the army and navy and of course Woolwich Arsenal had been successfully developed from its early roots in the 16th century into a major military manufacturing and laboratory complex. By the the beginning of the 19th century the Board of Ordnance had become "... a large Department of State of considerable power and influence, second only to the Treasury". .3.

From this experienced and prestigious position it would seem fair to conclude that there must have been powerful reasons why the initial plan to produce military small arms in-house had not been implemented on a large scale. This notion gives support to the belief that the reasons why Government had taken almost half a century to adopt a major controlling stake in the manufacture of military small arms are not straightforward issues and require in-depth investigation. At first it does seem curious that the British gun trade had taken so long to arrive at a position of being apparently incapable of meeting the national demand for military small arms, both in quality and quantity, by the start of the Crimean conflict in 1853 (which Britain entered early in 1854). This appears particularly surprising when one considers that it was the low state of weapon stocks in Britain two decades before the start of the Napoleonic Wars which provoked the Government to establish the armoury at Enfield. On this occasion the Board of Ordnance considered the situation so serious that in 1779 J Colgate, an officer, was sent to supervise the setting-up of 40,000 stand of arms in Liege. Later Major General Miller was dispatched to Liege and Hamburg to supervise the setting-up and procurement of arms in the years 1794, 1795 and 1800. The inability of the British gun trade to supply the needs of the military had become so acute that by 1802 Lord Chatham was publicly complaining that the craft of military fire-arm making had virtually died out in England. .4.

If it is accepted that the main reason for establishing the "Ordnance" factory at Enfield Lock in 1816 was to ensure that British national interests and security would never again be put at risk by a chronic lack of serviceable weapons, as it had been at the time of the Napoleonic wars, then it would appear odd that Government had seemingly not learned any lessons from this earlier arms shortage. Astonishingly, it was again the outbreak of war, this time in the Crimea, that was to highlight the state of Britain's unpreparedness for major conflict, due once more to the lack of serviceable military small arms. This would further suggest that the question of the British Government adopting a major manufacturing interest in the production of military small arms was anything but a straightforward matter. Therefore, explanations for what would appear to be a dilatory approach to arms procurement are required if we are to gain an understanding of the issues at stake. We have identified a number of factors which accounted for the British Government remaining a relatively minor manufacturer of military small arms for over half a century, which will be analysed individually in Chapters Five and Six.

The wider debate on growth of the U.K. and U.S. light industry

The reasons why the industries of America were thought to be generally in advance of those in Britain during the first half of the nineteenth century has caused much discussion among economic historians and historians of technology. Over the years a number of hypotheses have been put forward as to why these differences existed and how they had come about. The economic historian H.J.Habakkuk has suggested that both Britain and America had similar opportunities to design and install new manufacturing equipment. He goes on to pose the question "how far the rapidity of American mechanisation was due to the stimulating effect of bottle-necks, and in particular to a scarcity of labour"? .5. Here Habakkuk suggests, in simple terms, that due to the shortage of labour American industry was forced to exploit machine manufacturing methods. However, in his analysis of the situation, he expresses doubts about other commentators conclusions with regard to the scarce labour argument. For example, Habakkuk is generally dismissive of the explanations and observations for the technical progress of American industry given by the respected Victorian engineer Joseph Whitworth after he had visited the United States in 1853. Whitworth had commented "The labouring classes are comparatively few in number, but this is counterbalanced by, and indeed may be regarded as one of the chief causes of, the eagerness in which they call in the aid of machinery in almost every department of industry". .6. Similarly Habakkuk is unconvinced by the report of the "Committee on the Machinery of America", published in 1855, when it was suggested that the speed of mechanisation in America was provoked by the scarcity and high cost of labour. .7. Henry Pelling is treated in a like manner when he argued that American industry's rapid expansion into labour-saving machinery was caused by a general shortage of labour. .8. While Habakkuk initially seems to have some sympathy for Erwin Rothbarth, who has added to the debate when he argued "to attract labour the industrial wage had to be sufficiently high to prevent an effective alternative to the independent cultivation of land; and such a wage could only be paid if the American industrialist raised the productivity of labour by installing labour-saving machinery", in general he finds difficulty with this view also. .9. Habakkuk therefore asks what appears to be a very pertinent question, "If it paid American entrepreneurs to replace expensive American labour by machines made by expensive American labour, why did it not pay English entrepreneurs to replace the cheaper English labour by machines made with cheaper labour"? .10.

In addressing Habakkuk's question in relation to the British gun trade, there would appear to be a major fundamental difference between the way the small arms industries had evolved on either side of the Atlantic. In Britain, the small arms industry grew from a collection of modest sized gun makers over a period of several hundred years. For example the village of Birmingham by the middle of the sixteenth century was becoming known as a manufacturing centre, and it is recorded "many Smiths, Lorimers, Naylers and Cutlers" were to be found there at the time. Although 1603 has been suggested to mark the establishment of the Birmingham gun trade, the exact date when the industry became a separate branch of manufacture has not been exactly determined. .11. Pollard has listed more than thirteen hundred gun makers as opposed to merchants, most of them being grouped around London and Birmingham. .12. By the nineteenth century, the British Government, in the main, relied for its supply of military weapons on these small heterogeneous gun-smiths and out-work artisans. As research has shown, up to the middle of the nineteenth century the Government-owned part of the small arms industry was not capable of large scale production. The reasons for this will be discussed later in the thesis, where it will be revealed that "Ordnance" had not been able to expand small arms production from its own factory at Enfield, owing to the continued pressure upon Government by the independent gun makers. Due mainly to the uncertain nature of the contract system operated by "Ordnance" (to be discussed in Chapter Five), the private gun makers had resisted the installation of high cost capital equipment, particularly in the manufacture of locks and stocks, relying chiefly on the plentiful reserve of cheap labour. In summary, the British gun trade had reached the middle of the 19th century still largely rooted in the craft based practices of the past.

However, in the New World the American small arms industry did not have the luxury of time to experience the same evolutionary development as in Britain. In a way, by being a young country and a comparatively late industrial starter, American entrepreneurs could benefit from machine tool and other technological developments which had already become established in Britain and on the Continent, not necessarily in the small arms industry. In essence, it could be said that American industrialists had gained an advantage over their British counterparts by leap-frogging a large section of the technical evolutionary process. Often a pioneering development can bring disadvantages for the host country or company. This can happen when a competitor is able to capitalise on the later availability of the often cheaper "off the shelf" technology which has effectively allowed him to avoid the research and development costs.

Using a 20th century technological example as an illustration, Britain, in 1936, was the first country in the world to have a television public broadcasting service (405 line system). After the second world war improved television systems (625 line) were developed outside of Britain which were incompatible with United Kingdom standards, making it impossible for British manufacturers to export their indigenous product. Therefore, the home system rapidly became obsolete. .13. Hence, it is not always economically beneficial to be first in the field with a particular product or leading edge technology. In this particular example other countries were able to benefit from the pre-war television technology developed in Britain, adopting later and more advanced know-how in the post war period, free from dated technical constraints. In a similar way the American small arms industry had the advantage over its British counterpart in the time-scale of technical development. American weapon manufacturers had not been constrained by a traditional heterogeneous labour intensive small arms industry which had the ability to bring political pressure upon Government to maintain the status-quo. As it will be seen later in the thesis, the relationship between American machine tool and small arms manufacturers and their government was quite different from that of British manufacturers and "Ordnance".

There was of course a possible benefit for American industry in having a large influx of emigrant labour. These people coming from the Old World were looking for fresh opportunities and fortune in the new. Because they sought advancement for themselves and their families it is conceivable they would have been more amenable to change. This being the case, it is likely the new arrivals would have been willing to adopt a flexible approach to working with machinery which demanded a division of labour and in general did not require high levels of skill. It has been supposed that to the emigrant who had just entered the country and was eager to learn, machine intensive production would have distinct advantages for those who wished to establish themselves in work quickly. .14.

There is certainly evidence that because of the long craft based tradition, the British artisan did not welcome the notion of change which he saw as depriving him of a livelihood through the introduction of machines and this had to be resisted. Neither was the suggestion that new self-acting machinery be introduced welcomed by all the gun makers. Several of these men had come from family concerns and inherited the skills and status handed down by their forefathers. .15. These men were proud of their heritage and many were of the opinion that any move towards developing a machine based system of manufacture would not lead to improvements in the quality of the weapon and would eventually be detrimental to their trade. Indeed, we have encountered similar strongly held views even today, when conducting interviews with skilled gun makers within the private sector. There is also a considerable amount of evidence to be found in several 19th century Select Committee reports of the widespread belief that machines could not replace people. No doubt some who gave evidence were arguing from a protectionist stand-point, although there were others who could be regarded as artists in wood and metal who genuinely believed manual skills could not be bettered.

As already suggested, there was considerable reluctance amongst the small gun-masters to mechanise, there being little incentive to invest in costly capital equipment. Their unwillingness had chiefly resulted from the short term and intermittent nature of the contract system as operated by the Board of Ordnance. .16. Any financial advantage which might have been gained from the installation of new plant and machinery to produce standardised parts could not sensibly be justified in the short term. A system, of manufacture which would cut weapon assembly times thereby reducing the necessity for skilled hand finishing, would no doubt have been off-set by the high capital cost of the equipment. From the position of the small producer there was little to be gained from an "Ordnance" procurement system which could not guarantee continuity or regularity of orders. Furthermore, if any new machinery was to be maximised to the full by encouraging the manufacture of standard products, then the private sector would lose the flexibility to produce a range of non-standard weapons to satisfy the varied requirements of their long standing customers which was a major traditional advantage.

From the available evidence, there would appear to be no dispute between economic historians and historians of technology. They agree that American light engineering industry by the middle of the nineteenth century was considerably ahead of its British counterpart in the application of machinery to the production of small arms. Where there is not general agreement is on the answer to the question, why this should be?. The matter is probably best summed up by Ames and Rosenberg in their article "The Enfield Arsenal in Theory and History" when they state:-

> The central issue in the historical literature on technical change in the nineteenth century seems to be this: Americans clearly led the British in the adoption of many machine methods of production. If this precedence is not simply "Yankee ingenuity" working in a void it must reflect such economic factors as resource endowment, the structure of the labour force, the structure of prices and the nature of

> consumer tastes. The simpler techniques of analysis reveal that several variables must be considered simultaneously. The working historian will naturally wish to keep his explanation as simple as he can. .17.

While this latter advice would appear eminently sensible, the task of analysis has not been made easier by the endeavours of many commentators who have wrestled with the subject in the hope of making a decisive break-through. A scholarly attempt by Eugene S. Ferguson to examine the differences in manufacturing technology between America and Britain by drawing together the writings of many technological, economic and social historians clearly demonstrates that the subject under discussion is highly complex with many influencing strands. .18. This suggests that the debate is set to continue for some time unless new evidence can be found to explain the reasons behind Britain's 19th century technological pause.

A different approach

From the early part of the 19th century the American National Armouries had experimented and developed techniques to standardise the manufacture of small arms by machine methods, while in Britain within the private sector there was resistance to change from a traditional labour intensive system which had been in operation for several hundred years. However, in America the government had taken the initiative to encourage small arms production by machinery, even going as far as to invite public sector engineers and entrepreneurs to develop their ideas within the confines of the national armouries. .19. In Britain this approach was not followed and was effectively discouraged. Differences in the Government's approach to manufacturing between the two countries are most graphically illustrated in the production of the gun stock, the first major musket component of complexity which American engineers were able to produce successfully by machine methods in a standard form. The progression to the eventual development of the second generation of sequenced self acting machines took many years to perfect, and it is arguable, that without the active encouragement and support of the American Government, the programme would at best have been delayed and at worst not commenced.

Professor Arthur Marwick, amongst others, has argued that the early 19th century development of machine intensive production by American industrialists and engineers followed from the demand for arms as a result of the rapidly expanding frontier. .20. Yet pressures to move from labour intensive small arms production would seem to have been just as great for the British Government. Early in the century Britain was committed to a large scale military role, the war with France, and there was of course the constant discipline of policing her widely spread Empire. Therefore, in the face of this large scale requirement for weapons, Marwick's argument does not explain the reasons why British small arms manufacturers apparently favoured labour intensive methods of weapon production.

It will be recalled that a disparity in wage rates has been suggested to account for the differences in the speed and scale of manufacturing development between Britain and the United States. In America high wages were paid to ensure the scarce resource of labour was drawn toward industry rather than enticed to purchase cheap land. This, it is argued helped contain costs by stimulating the growth of machine intensive production. Further factors making American labour scarce and expensive were said to be the sparsity of the population and the high cost of transport. In contrast, the industrial towns of Britain were situated next to densely populated areas where the poor lived, so advantage could be taken of this cheap and plentiful resource. It is reasonable to assume that cheap labour helped sustain the sub-contracting element of the independent gun trade, giving it a cost competitive edge over the generous terms and conditions enjoyed by those working in government industries. .21. This might explain in part the reluctance of British small arms manufacturers to pursue capital intensive programmes, but it does not go far enough. However, if Habakkuk is correct in his abundance of cheap labour hypothesis, suggesting that British manufactures should have been able to build machine tools more cheaply than their American counterparts, it would seem to imply that powerful reasons were preventing this plentiful resource from being used in the machine branch of engineering. .22.

Nathan Rosenberg has contributed to the debate by arguing that British industry was technologically ahead of America in the eighteenth and early nineteenth centuries, because of the need to seek and develop alternatives to the diminishing supply of wood as a fuel and raw material. He suggests that America, unlike Britain, had a rich abundance of forest products which directly accounted for the way in which her technology advanced. Making the point quite succinctly he states:-

Whereas much of Britain's early industrialization should be

> understood as a deliberate attempt to overcome the constraints imposed by the dependence upon organic materials, Americans possessed no similar inducement. In fact, a key to much of early American industrialization - certainly until at least the middle of the nineteenth century - should be understood in terms of technology specifically geared to the intensive exploitation of natural resources which existed in considerable abundance relative to capital and labor. This background information is critical to the explanation of the fact that, in spite of America's late industrial start as compared to Britain, she quickly established a worldwide leadership in the design, production, and exploitation of woodworking machinery. .23.

Rosenberg's abundant natural resource argument may go some way towards explaining why American manufacturers developed and exploited machinery but, like the other arguments, it does not fully explain why British manufacturers, who after all possessed knowledge through earlier industrial innovation, did not seek to exploit machine intensive methods by further making "... a deliberate attempt to overcome the constraints imposed by the dependence upon organic materials ...". For example the mechanisation of gun stock production did not occur in Britain until American machinery was imported and installed at the Royal Small Arms Factory, at Enfield Lock, in the mid 1850s. While it was known that the application of wood-working machinery was generally more wasteful of the scarce raw material than the employment of skilled hand labour, there is no evidence to suggest that this was ever used as an excuse for British small arms manufacturers to deliberately reject the introduction of machine tools. As Rosenberg and others have argued, it was British manufacturers who were ahead at the beginning of the century in mass production technology with the manufacture of uniform parts. What has not been satisfactorily explained is how the technology seemingly paused and why the future advantages which could have been gained for British manufacturers were allowed to be developed by their American counterparts, making them leaders in the field of machine tool production. The final irony was that the British Government was forced to purchase large quantities of machine tools from America in 1854 and 1855 to equip the factory at Enfield Lock.

As research will show in the following chapter the powerful reasons preventing the development of light engineering machine tools in the U.K. was inter alia, associated with demand and the reluctance of the largest customer, the Board of Ordnance under the control of the British Government, to operate a contract system which would have given the private gun trade the incentive to invest in capital equipment.

The notion that the ending of military conflict between Britain and France after 1815 had somehow suppressed the need for a complete overhaul of the way weapons were produced and acquired for the armed forces cannot be accepted as a valid reason for the seeming pause in the transfer of the new machine technology (developed during the 18th and early 19th century) to Britain's small arms industry. Given the perilous state of weapon stocks at the time of the Napoleonic War, coupled with the long and deep distrust of the French, it would seem unreasonable to believe that the British Government would have left the defence of the realm vulnerable for almost forty years. .24. This therefore suggests that other powerful reasons existed which prevented the Board of Ordnance pursuing its original plan to develop Enfield as a key weapon supplier.

While the private gun trade would appear to have had valid reasons for not totally embracing mechanised production methods early in the century, any notion that industry as a whole had rejected the new machine technology wholesale was patently not true. As already pointed out by Rosenberg and others, in the preceding period of the 18th century Britain had experienced the start of the industrial revolution with the technological advancement of the cotton industry from hand labour through water to steam power, creating a boost for trade and expanding opportunities for exports. .25. Consequently, it can be seen that the British Government not only had the opportunity but also possessed the technology and the motive to develop, expand and modernise the military side of her small arms industry. However, it would appear that for some reason the motivation was lacking and it is this particular aspect which requires investigation.

On the other side of the Atlantic, at about the same time as the British Government was faced with the decision to improve its methods of procurement of military weapons, it might be concluded that there was no great urgency for the American Government to build up weapon stocks. Once the 1812 to 1814 hostilities between Britain and America had ceased, it could be argued that the American nation had little need to expand or equip her armed forces, for unlike Britain she had no powerful enemies on her door-step. This point is made by Professor Peter Parish who has suggested that the American Government spent a far lower proportion of her national income on military power than the majority of developing countries in the western world.

.26. While this would seem a rational observation to make, Merrit Roe Smith has pointed out that after the American Government had taken control of the two national armouries (Harpers Ferry and Springfield) in 1815 the problem of "Thousands of arms [which] had been damaged and rendered virtually useless during the recent war with England" had to be addressed. He goes on to say "...the immediate concern was the production of cheaper, more uniform weapons that could be repaired in the field by substituting new parts for broken ones". .27. This was of course the beginning of the exercise which led the American Government, engineers and entrepreneurs into a long and costly programme of standardisation and machine tool development. Whatever the reasons were which motivated the American Government to take a different route to her British counterparts in the manufacture of small arms during the first half of the 19th century can be debated at length. However, what seems clear from the evidence is that both Governments had exactly the same opportunity to review their arms procurement procedures at about the same time. Therefore, the question still remains, what caused the British Government to effectively discourage the private sector military gun trade from modernising its methods of production, allowing them to retain labour intensive manufacture to the middle of the century?

Understanding the task

There is little doubt from the research already carried out that the subject under investigation, that of apparent British backwardness in small arms manufacturing technology in the first half of the 19th century is multi·faceted and highly complex. It is probably for these reasons that the debate surrounding this particular issue looks set to continue and why the subject has held scholarly interest for so long. H J Habakkuk, in evaluating the various economic arguments for technological development on both sides of the Atlantic, recognises that a high degree of complexity exists. When discussing his observations in the context of factor-endowment he suggests:-

> There is no reason why abundance of a factor should not have been favourable to technical development in one set of circumstances and scarcity of the same factor favourable in another. The influences which are relevant to development combine in many different ways, and has a different effect according to the combination in which it appears. Arsenic cures in small doses and kills in large. But this does not dispense with the need to decide which doses are homoeopathic and which are lethal. It is clearly unsatisfactory to say that cheap-labour countries grew because their labour was cheap, and dear-labour countries because their labour was expensive. .28.

While it can not be denied that the subject under examination requires several lines of research, directing the investigation towards what slowed or delayed Britain's once held technological supremacy would appear to be a clearer route to follow in the quest of understanding why the British small arms industry developed in the way it did. These issues will be brought out and discussed in the following chapters. However, it should be understood that the investigation is not about claiming intellectual property rights for one country or another. Therefore the writer does not wish to imply through the research findings an air of what might be construed as a recurring British malady - "invented here, developed elsewhere".

NOTES

.1. Gilbert, K R, The Portsmouth Blockmaking Machinery, HMSO, (London, 1965) pp.1-4; see also Rees's Cyclopaedia, Strahan & Preston, (1819) pp.5-24, plates 1-7; also Cooper, Carolyn C, "The Portsmouth of Blockmaking", Technology & Culture, Vol.25 No.2 (April 1984) pp.182-183
The average 74 gun warship needed almost 1000 pulley blocks for the handling of sails and the positioning of guns. The Royal Navy required in the order of 100,000 of these devices each year. Bentham, who already had an appreciation of wood-working machinery, no doubt saw an opportunity of solving the navy's needs almost overnight.
Prior to Bentham's initiative, the Navy had been supplied with pulley blocks by Taylors of Southampton from around the middle of the 18th century. This family firm had over the years pioneered improvements in the manufacture of blocks by mechanising certain turning and sawing operations, first by horse power and then by water power. In fact, Walter Taylor is said to have invented the circular saw, while his son Samuel in the 1770s had standardized and reduced the material content of the ships blocks supplied to the Navy.
A comprehensive account of the working of the block making machines can be found in Rees's Cyclopaedia of 1819.

.2. Gregory, Charles Hutton, "Address of the President", Institute of Civil Engineers Minutes of Proceedings, Vol.27, January 14, 1868 p.186

.3. Skentebery, Norman, Arrows to Atom Bombs A History of the Ordnance Board, HMSO 1975 p.14

.4. Roberts, G H, History of the RSAF Enfield Lock, unpublished history, c1930, p.C3

.5. Habakkuk, H J, American & British Technology in the 19th Century, Cambridge University Press, (Cambridge, 1967) pp.4-9

.6. Ibid., pp.4-9
Habakkuk has mistakenly shown the date of Joseph Whitworth visiting America as 1851.

.7. Ibid., pp.4-9

.8. Ibid., pp.4-9

.9. Ibid., pp.4-9

.10. Ibid., pp.4-9

.11. Dunham, Keith, The Gun Trade of Birmingham, The City of Birmingham Museum and Art Gallery Department of Science and Industry, (Birmingham 1955) p.5

.12. Pollard, H B C, A History of Firearms, Lenox Hill, (New York 1973) pp.284-296

.13. Lewis, James H, The U K Consumer Electronics Industry - Death or Survival? D.I.R.T.U.S. Dissertation, Middlesex Polytechnic, (Enfield 1979/1980) pp.1-4

.14. Coleman, Terry, Passage to America, Hutchinson & Co., (London 1972) pp.294-299. From the figures produced by Coleman, it can be seen that the majority of people entering the United States of America towards the middle of the 19th century were predominantly unskilled.

.15. Op.cit., Pollard, pp.284-296
It can be seen from the listing of dates and names of the many gun makers that there were several family businesses.

.16. House of Lords Record Office, London.
Letter from the Inspector of Small Arms, respecting the Disadvantages of the System pursued for obtaining Arms, George Lovell, 16th December 1848. Included under, Appendix to Report from the Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.454 (492)

.17. Ames, Edward & Rosenberg, Nathan, "The Enfield Arsenal in Theory and History", The Economic Journal, December 1968 pp.841-842

.18. Ferguson, Eugene S, Yankee Enterprise, Editors: Otto Mayr & Robert C. Post. Smithsonian Institute Press, Washington, 1981. "History and Historiography", pp.1-23

.19. Smith, M R, Harpers Ferry Armoury and the New Technology, Cornell University Press, (London, 1977), pp.124-129
It can be seen from the examples of Blanchard and Hall that considerable encouragement was given to these engineers by the American National Armouries to develop their ideas in-house. Also see; Lewis, James H, "The Quest to Bring the "American System" to the Enfield Armoury", Tools & Technology, Fall 1995, p.4

.20. Marwick, Arthur and White, Larry, From Hand Craft to Mass Production - the Gun Industry in America, Open University Programme, BBC2, 7.30am 17/4/1994

.21. House of Lords Record Office, London.
Examination of Mr John Stephenson, 29th March 1854, Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.319 (357)

.22. Op.cit., Habakkuk, H J, pp.6-16

.23. Rosenberg, Nathan, America's Wooden Age: Aspects of its Early Technology, Sleepy Hollow Restorations, (New York 1975), pp.40-41

.24. House of Lords Record Office, London.
Memorandum from Secretary, War Office, J. Wood, 18th February 1854. Included under, Appendix to Report from the Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, pp.451-452 (489-490)
It is clear from Wood's memorandum that the problems with small arms procurement by "Ordnance" had been identified from the early part of the century.

.25. Hobsbawm, E J, Industry and Empire, Penguin Books, (London, 1986) pp.58-59
One of the greatest advances in the history of technology came about during the 18th century when Abraham Darby developed the process of smelting iron with coke at Coalbrookdale. Surprisingly this process for ferrous metal production has changed little over the years. The basic principles are still in use today. Coupled to the developments in iron and cotton technology, was the expansion of the road and canal systems which provided the necessary transport infrastructure to supplement and support the growing export and home markets. See, Harris, R J, The British Iron Industry 1700 - 1850, Macmillan Education, (London, 1988) pp.30-31

.26. Parish, Peter, What Made America Different in the 19th Century, Paper given at Middlesex University, (12/5/1994)

.27. Smith, Merrit Roe, Harpers Ferry Armoury and the New Technology, Cornell University Press, (London, 1977), p.106

.28. Op.cit., Habakkuk, H J, pp.2-3

THE "ORDNANCE" CONTRACT SYSTEM AND THE "VIEW"

In this chapter the opportunity will be taken to examine the relationship between the Board of Ordnance and the private gun trade which pivoted on the Government method of small arms procurement. To help understand the interplay between the private and the public sectors, it will be necessary to explore the workings of the "Ordnance" contract system and to discover how "the view" (inspection) was performed by "Ordnance" personnel. By studying these two areas and their effect upon the private gun trade, particularly in the period from 1840 to 1854, we can resolve a number of complex issues. While research has shown that there were several reasons governing the slow progress of British industry in the 19th century towards a fully mechanised system of small arms manufacture, in many ways it was the "Ordnance" viewing and contracting systems which had the strongest influence upon the industry's shape and structure. Because of the complicated and multifaceted nature of "Ordnance" practice, the pivotal role played by the Inspector of Small Arms, George Lovell, will be treated in greater detail in the following chapter. There, a reassessment of the available evidence will allow a fresh look at the influence of this complex and talented man upon the operation of the "Ordnance" small arms inspection and procurement which was firmly linked to the functioning of the weapons contract system.

To assist this study and to gain a better understanding of how "Ordnance" viewed the performance of the independent gun trade during the first half of the century, it will be necessary to look at the prevailing situation from an "Ordnance" perspective. Fortunately a detailed and quite vivid account of the "Ordnance" viewpoint survives, recorded in a memorandum written on the 18th February 1854 by Joseph Wood, Secretary, War Office, which encapsulates the unsatisfactory history of weapon supply as he saw it. From the text of the memorandum it is possible to detect the increasing tension between "Ordnance" and the private sector.

Wood's memorandum

Hghlighting the relevant sections of Wood's memorandum allows the backdrop of events to unfold, giving a clear image of the circumstances which were to dramatically change the methods of weapon supply and procurement for the British armed forces:-

> In 1803, when the war with France was renewed, the scarcity of arms was so great, and the want of them so urgent, that the Government had recourse to foreign markets, and bought up all they could obtain. These were bad in quality, cumbersome and heavy in pattern, and comparatively few in number. ... At the peace in 1815, the manufacture of arms for Government ceased, and the workmen were dispersed. Little was afterwards done with regard to the provision of arms, until the adoption of the percussion principle, when a re-equipment of the army became necessary. The trade had fallen into a very disjointed state, and there was a difficulty in collecting together men capable of making the new arm in a satisfactory manner. In 1840 the inspector of small arms represented the very unsatisfactory state of affairs; the masters complaining of the workmen, the workmen of the masters; the lock-filers and the stockers striking for wages; the masters exposed to serious combination of workmen, and the latter having a fair ground of complaint against the masters; the result being higher prices to the department, or injury to the service by delay.
> Again, in 1842, the inspector of small arms represented the injury to the service, ... and in 1848 he further represented the disadvantages of the system then pursued for obtaining arms, ... The opinions of the inspector of small arms expressed coincided with those which the Board had previously entertained. ... In March 1850 they decided upon putting up to competition the supply of arms then required, for calling for tenders of the several parts of the musket except the stocks, of which there was a store, and then for setting them up. The result showed a great reduction in the cost of the arms; ... Many of the tenders were at one price, showing that

> the parties had acted in concert, ... Great difficulties arose in the execution of the contracts; the setting up was delayed for want of materials, the lock-filers having struck for wages; and it was also impeded by the very unsettled state of the workmen in the military-gun trade generally.
> In February 1851 the Board were desirous of obtaining a further number of muskets, before the end of the financial year, 31st March 1851, but were informed by the contractors that there were not enough workmen in the trade to enable them to increase the number they were under engagement to supply.
> In May 1851 a new pattern rifle musket was adopted by the British Army, and tenders, by competition, were obtained for the supply of the materials requisite, in addition to those in store which were applicable, for setting up 28,000 rifle muskets. Great delays occurred in the supply of the materials, and sufficient were not collected to enable the Board to make contracts for setting up the muskets, until the month of December 1851; and the muskets were not completed until November 1853.
> ... In January 1853 a new pattern rifle carbine was adopted for the artillery, and the contracts were made for the materials for setting them up; but so great has been the difficulty and the delay in obtaining them, notwithstanding all the efforts of the Board, that not more than 500 carbines were completed by the end of January 1854.
> The rifle musket of 1851 having been superseded in 1853 by another of smaller bore, and somewhat different construction, the Board, in July last, called for tenders for materials for 20,000 muskets of the latter description. The offers received were so unsatisfactory as to price, and evinced so perfect a combination amongst the parties, that they were, after some correspondence, declined; ... The consequence is, that, up to the present time, the Board have not been able to commence the setting up of the muskets; and though they have made a contract for that purpose, it is uncertain, even if the materials should now come in with regularity, when it will be carried out, from the difficulties which the contractors may again encounter from the workmen. .1.

From Wood's memorandum, it can readily be established that after almost half a century the Board of Ordnance had hardly improved its position as a weapons procurer. As the second half of the century began, the Board was still unable efficiently to equip the British Army with small arms. This was the sorry state in which "Ordnance" found itself after initially planning to avert such future disasters by constructing the factory at Enfield Lock in 1816. The predicament poses two questions. How had such an unsatisfactory set of circumstances arisen after active measures had been taken to rectify the problem of arms supply, and was the position as one-sided as Wood had described?

Procurement problems

Prior to 1850 the contract system of arms procurement relied on "Ordnance" working with an established list of approved contractors. These contractors in turn used their own discretionary authority to employ sub-contractors and to engage the workers they required. There was considerable distrust between "Ordnance" and the private sector almost from the start. In May 1816 the Birmingham and district gun manufacturers held a meeting which passed a resolution opposing the Board of Ordnance on the erection of the Enfield factory. Subsequently a petition was drawn up, but not presented to Parliament. "Ordnance" subsequently made an offer to the private sector only to use the facilities at Enfield for repair and not the manufacture of small arms. This promise was accepted by the trade. .2.

The short term nature of the contract system and the strictness of the view had resulted in complaints to Parliament by the independent gun trade through their political representatives. This had helped create difficulties and delays for "Ordnance" in their weapon procurement programme. Tensions did not improve between the two sides when George Lovell was promoted to Inspector of Small Arms in 1840. Lovell effectively took responsibility for every aspect of military weapon procurement. Under him, the "Ordnance" inspection system of gauging and measuring to pattern was tightened, no doubt spurred on by the drive towards improvements in standardisation he had begun at

Enfield. Tolerances were becoming so stringent that contractors were having great difficulty in getting their work accepted by "Ordnance". The private gun trade suffered considerably from the high rate of rejection and were in constant fear that Enfield would eventually undertake all military business in-house. This was the unsatisfactory state of the military gun trade as the second half of the century commenced. With war looming in the Crimea, the British Government found itself placed in the same embarrassing position it had been nearly half a century before at the start of the Napoleonic conflict, that of not having the ability to supply good quality arms in quantity to the front line troops.

Examining correspondence between the Board of Ordnance, the new Inspector of Small Arms, R W Gunner (promoted after Lovell's death in 1854), and some of the private contractors in the period September 1854 to March 1855, suggests that the demands and requirements of the "Ordnance" arms procurement programme had unfairly placed great strain upon the private contractors. In a letter to Joseph Wood, dated 12th September 1854, the Birmingham contractor Hollis & Sheath stated "we believe that we can complete the 20,000 musket pattern 1853 in March next, providing we have the materials (less sights) issued to us at the rate of 200 each per week from this date. We have received up to the 9th instant 10,000 sets". The letter goes on to explain:-

> We beg again to assure the Honourable Board that every effort is being made to supply the sights so as to keep the pace with the setting up and we have already made from 9 to 10,000 sights, the greater part of which have not passed the view but we shall be able (as soon as the proper tools are prepared for viewing the sites) to deliver them in such quantities as to

fetch up the lost time. .3.

At first glance the reference in the letter to the tools not yet having been prepared for viewing the sights, might imply self criticism on the part of the contractor for failing to produce these items on time. However, reading a later letter from the contractor dated 16th November 1854 to Wood does place a somewhat different interpretation on who should be supplying the tools. In the correspondence Hollis & Sheath state that between 27th May and 28th October 1854, they had delivered 14,636 sights for viewing. Out of these, 8,613 had been "marked" (passed inspection) and 5,823 rejected. The following section of the letter is most revealing when the contractor complains "We believe that the immense number of rejections would not have taken place had the viewers been supplied with proper tools to test their accuracy - to which we refer in our letter of September 12th and with which tools the viewers have not yet been supplied". .4. While it can not be categorically deduced from the correspondence that "Ordnance" should have actually made the tools, there is certainly a strong implication that they were responsible for their supply on time in support of the contract. The reference in the correspondence to "the viewers" not being supplied with tools seems to imply the "Ordnance" viewers rather than those employed by Hollis & Sheath. However, even if this was not the case "Ordnance" would still be at fault for being the root cause of the delay.

A further revealing piece of evidence comes to light when examining a letter from R W Gunner to the Board of Ordnance, dated 22nd November 1854, in response to complaints of delays in the delivery of the pattern 1853 musket. Gunner reported that between April and November 15th, 16,880 sets of material had been issued, but he had only received 8,080 completed sights. Interestingly, there is no mention of tools not being supplied to the viewers. However, he does go on to say "sights have been obtained from other sources and issued for their service making up the numbers as stated by the contractors to about 10,000 Rifled and Sighted, where as only 5,000 finished arms had been delivered up to the 6th instant". .5.

On 2nd March 1855 the Board of Ordnance wrote to Gunner regarding the contract for the 20,000 pattern 1853 muskets entered into on 21st February 1854, reminding him that "the whole should be delivered by the 5th March". Gunner responded on 10th March, reporting that the "four old contractors" had delivered 18,406 pattern 1853 [muskets] which had all passed the view, and that he had another 385 muskets in hand, leaving an outstanding balance of 1,209. On 31st March 1855, Gunner wrote to Wood "I beg to report to the Honourable Boards information that the four old contractors have delivered 20,000 Musquets Rifle Pattern 1853 (first pattern) in completion of their contract of the 21st February 1854". He then went on to give the following totals as "set up and finished complete":-

Set up Birmingham	20,000
Set up Enfield	1,000
Set up London	1,500
	22,500 .6.

Studying the evidence surrounding this particular contract has revealed what might be construed as a "cover-up" on behalf of certain individuals working for the Board of Ordnance who appear to have either withheld or not supplied important gauges (Fig.11) or patterns to the contractors. This may have been an individual deliberate act, and not necessarily a piece of "Ordnance" collusion. However, in the future the incident along with other similar examples could easily strengthen the Board's hand when arguing the case for expanding the Enfield Lock small arms manufacturing facility, on the grounds of the gun trade's inefficiency. This would be a trump card to play against the private sector's opposing Parliamentary lobby. Although the Board was eventually to take a major controlling interest in the manufacture of military weapons by the introduction of American manufacturing technology at Enfield, this was not before a complex series of events had unfolded.

Unfair criticism?

Although the private gun trade had been much maligned over its poor manufacturing and delivery performance by "Ordnance", perhaps in some instances rightly, nevertheless, with regard to the contract for 20,000 weapons, it has been shown that in spite of being denied specialist setting-up tools, a substantial order had been completed within a few weeks of the agreed date. This was achieved in the face of strict viewing procedures, a reliance on hand production methods and, as Wood had pointed out in his memorandum dated 18th of February 1854, "there was a difficulty in collecting together men capable of making the new arm in a satisfactory manner". .7. While the information above suggests that the fault was not always with the private sector, there is, in addition, further strong evidence which is at variance with the "Ordnance" criticisms of the gun trade. This information also conflicts with the generally accepted view of arms experts and historians like De Witt Bailey who have suggested that at the time, there was within the gun trade many "slovenly workmen". .8.

Giving evidence to the Select Committee on Small Arms in March 1854, Colonel John George Bonner, the Inspector of Stores to the East India Company for the past twenty-one years, when asked, "How do you provide your supply of fire-arms"? Replied:-

> As regards the musket, the materials are provided from various bona fide manufacturers at Birmingham and its neighbourhood, such as locks, bayonets, barrels, ramrods, and brass work; the smaller articles, such as screws, nails, swivels, and the minor parts of the gun, are entrusted entirely to the setters-up, viz., the gunmakers of London, and they provide the stock also, the Company not deeming it advisable to accumulate a store of stocks; no difficulty has been found in getting them at all times from the gunmakers in London; that forms part of their charge of course for setting up. .9.

From Bonner's evidence it can be seen that the East India Company between the years 1840 to 1851 had taken 329,340 stand of arms from the private gun trade, the year 1847 to 1848 having the maximum total of 58,180 weapons. One of the most revealing pieces of information taken from Bonner came during a series of questions relating to the East India Company's acceptance standard for weapon quality. When the point was put to him "You view them much in the same way as the Government view their muskets, do you not?" Bonner replied "Just the same". .10. It can readily be deduced from following the probing cross examination that Bonner and his highly experienced long serving assistants were the final arbitrators in any controversial issues over standards of acceptable quality. One gets the distinct impression that should a dispute arise over the dimensions or finish of a particular weapon or part, then a practical common sense settlement would be found and mutually agreed.

In the continuing cross examination Bonner was asked "When you have required so large a supply as 58,000 for one year, and 48,000 for the next year, have you found the contractors raise their prices?" To this Bonner replied "Never, except it was called for by those circumstances which enhance all prices". .11. Interestingly, and in contrast, Wood in his memorandum of 18th February, had complained of "...high prices, which resulted from the organised combinations both of the masters and men in the gun trade ...". .12.

When probed deeper on the subject of charges, "You met with nothing unfair on the part of the contractors?" Bonner made the following telling statement which implied a good working relationship between customer and supplier. He explained, "I must do them the justice to say that they were always particularly anxious to do what was right and proper between the Company and themselves, which is my duty to watch". .13. This display of mutual trust appears genuine and probably accounted for the East India Company getting the weapons they required at the right price. In fact there is evidence of the good relationship between the private sector and the East India Company, and the somewhat strained alliance between the Board of Ordnance and the gun contractors, dating back to the 18th century. At the time a dispute arose between "Ordnance" and the private sector over the design, price and conditions of a contract for the manufacture of the pattern 1777 flint lock. On this occasion the East India Company were having a simpler form of the lock manufactured for which they paid the contractors one shilling more than "Ordnance" were offering. Not unnaturally, their work was given preference over "Ordnance". .14.

Further evidence of fairness and a good working relationship can be seen when inspecting the price of some popular 19th century weapons. Although not exactly the same as the then current British service pattern, by 1850 the cost of a weapon to the East India Company from the private sector was £2-7s-7d, which at the time was not excessive. .15. This figure compared more than favourably with a Baker rifle costing £4-8s-3d in 1810, or the Minie rifle manufactured at the RSAF Enfield in 1853 costing £3-4s. .16.

With regard to pricing, it should be remembered that "Ordnance" had a distinct advantage over the private sector, as Enfield had the ability to estimate the various manufacturing costs. However, the gun trade, being denied long term contracts, were reluctant to invest in capital equipment which over a reasonable period of time would have helped reduce the labour cost content of a weapon. Allegations by "Ordnance" of the private sector overcharging may have been the result of contractors trying to maintain sensible profit margins to compensate for high reject rates and the short term nature of the contract system, rather than a deliberate policy of making excessive profits from the

Government. This observation would appear to be validated if the quantities of weapons delivered (shown later in this chapter) to the East India Company and "Ordnance" are compared. Over a nine year period (1841-1850), the private sector sent on average almost three guns to the former, against only one to the latter, suggesting that the best prospects for the future of the independent trade lay with customers like the East India Company rather than "Ordnance".

"Ordnance" on the other hand were supported by, and were part of, Government. Before the end of the 1850s Enfield, a public sector factory, would receive substantial internal orders for weapons allowing them to sustain high annual volumes of production. While it is beyond the scope of this thesis to examine the methods of "Ordnance" financial accounting to see if all overhead costs had been properly administered and apportioned to the weapon, it is however recognised that government departments have historically been clever at concealing the true cost of products and services through the vastness of the budgetary machine. Therefore, without an in-depth study, it would not be possible to guarantee that the "Ordnance" price for a weapon supplied to the military reflected all the attributable overheads, like warehousing, material deterioration or wastage, packing and transport.

The importance of good relationships

The concept of a good working relationship between customer and supplier is one that should not be overlooked, as often it can provide vital clues and broaden our understanding of why a particular set of circumstances arose, or why certain situations prevailed. From Wood's memorandum of 18th February 1854, it can be seen that relationships had remained strained between "Ordnance", the contractors and their workers for a number of years, as he speaks of "...organised combinations both of the masters and men...". .17. This, he implies, caused contractual delays and higher prices for "Ordnance". However, as with all forms of accusations and counter accusations, there is seldom one side which is completely innocent or correct in its assessment of the situation. Reasons governing the difficulties are often complex and not always what they appear on the surface. Under such circumstances, there is a need for mutual trust and understanding if issues of difference are to be resolved. Although there were some calm and conciliatory voices from within the ranks of the gun contractors, there was a growing general belief that "Ordnance" was planning to take away their livelihoods by increasing the number of manufacturing functions carried out in-house. As it will be seen later, the fears of the gun trade were not without foundation.

It is quite usual today to discover examples of strained relationships between customer and supplier, resulting in lack of mutual trust. Often the customer will take advantage of the contractor or supplier, when the market demand for the product is weak, by offering a lower price. This is on the grounds of the product being more difficult to sell, which on occasions can be quite genuine. Nevertheless, when the market becomes buoyant, then it can be the turn of the contractor or supplier to take advantage of the customer by putting up the price, often on the grounds that material costs have risen, prompted by increased demand. Both forms of commercial blackmail are the basis for distrust, each party awaiting the earliest opportunity to regain the upper hand. When such breakdowns in relationships occur, it is normal for the customer to seek to place business with other contractors or suppliers, while the supplier strives to gain contracts with other customers. Such behaviour is not conducive to the maintenance of good quality products, as both customer and supplier have to go, once more, through a fresh learning cycle with their new partners. Inevitably this can lead to higher product reject rates as new procedures are adopted, with the added risk of failure to meet delivery schedules. While these may not have been the exact circumstances experienced by the Board of Ordnance and the private gun trade, research has revealed that a number of the elements outlined certainly existed, particularly when "Ordnance" moved from a list of established contractors to the open tendering system in 1850.

These complex issues of relationships, the short term intermittent nature of contracts, the strictness of view, and what might be seen as the delaying or withholding of essential measuring equipment by "Ordnance" made up a cocktail of events which in turn eventually influenced Parliament into voting large sums of money to re-equip the Royal Small Arms Factory at Enfield Lock with the latest American machine tool technology. This action thereby enabled "Ordnance" to take virtual control of all military small arms manufacture. However, in the ensuing period until the improved manufacturing facility was firmly established, the private gun trade was to be called upon once more to supply the British Army in time of war.

A different relationship

It would be difficult for the researcher sifting through the considerable documentation of the period not to escape the clear impression that there was a general feeling of mutual respect and trust between the East India Company and the private gun contractors. This understanding had developed over a number of years, resulting in a good long term working relationship. Much of this had come about through the stewardship of Colonel John George Bonner with his more practical approach to the viewing of arms. The same could not be said of the relationship which existed between the private contractors and the Board of Ordnance. Much of the ill feeling came about after George Lovell was promoted to Inspector of Small Arms in 1840, when he had insisted on stricter standards of viewing for weapons and parts. Lovell's endeavours to improve the quality of British military firearms and, to his credit, the contractual relationship with the independent gun trade were generally not understood, lacking the whole-hearted support of "Ordnance" (this will be discussed in the following chapter). The years from 1840 to the middle of the century saw a rapid deterioration in the relationship between the private gun trade and the Board of Ordnance, with increasing acrimony, much of the venom being directed at Lovell.

By the time Joseph Wood had written his critical memorandum on the performance of the private gun trade in February 1854, and Bonner had given an opposing view in his evidence before the Select Committee on Small Arms in the following month of March (this being given some prominence in the Committee's summing up in the May), the situation had been overtaken by events. On the 28th March 1854, Britain declared war on Russia which effectively loosened the private gun maker's lobbying grip on Parliament. In the national interest, Bonner's contrasting testimony would have to be ignored as "Ordnance" pushed home the initiative to expand the Enfield Lock manufacturing facility.

A misunderstood private sector

Several contemporary writers have given the impression that the private gun trade in Britain was woefully inadequate and generally slovenly in its performance, producing sub-standard weapons and parts. While one can understand how such an impression has grown and remained with some commentators, by examining the available evidence in detail a somewhat different and more balanced picture emerges.

The British private gun trade can be looked upon as being extremely flexible and adaptable in its methods of manufacture, coping with a range of weapon types. These essentially fell into three main categories. At the bottom of the scale there were the cheap flint-locks with beech-wood stocks made for the African market, at a unit price of around ten shillings. Then there were the different types of contract military patterns for supply to overseas markets and to the British Government, typically selling at £3-0 to £3-10s. At the top were the sporting guns or fowling pieces. These could command prices in the order of £18 or more. .18. Some of these sporting guns can be considered as lovingly hand crafted masterpieces, even desirable works of art, many having engraved lock plates and barrels, with highly figured and polished walnut stocks, the wood in the most expensive models coming from selected areas of the tree root.

Much of the criticism of the private gun trade had come from "Ordnance" sources such as Joseph Wood (alluded to earlier). No doubt from his particular point of view the situation of arms quality and delivery was as bad as it could be. When he wrote his memorandum in February 1854, giving his analysis regarding the state of the gun trade, it is doubtful if he was fully aware, or, for that matter, understood, the intricacies surrounding arms procurement, particularly the constraints placed upon manufacturers by the contract system. Due to the private gun trade being loosely organised around a flexible system of out-working, employing small jobbing artisans using mainly manual skills, it was able on the whole to cope extremely well with the three main categories of weapon manufacture. This was particularly true of the African and sporting gun trade, and that of the East India Company. Problems arose when the trade tried to fulfil contracts for the Board of Ordnance which did not appear to understand the nature of the private sector's business, and had therefore unilaterally set standards of high quality and finish. This level of perfection was not compatible with the more practical requirements set by other major customers, such as the East India Company. Naturally these differing standards for military weapons caused confusion and even resentment among the private contractors, as large numbers of their arms were rejected by the "Ordnance" viewers, when their work was generally accepted elsewhere. If "Ordnance" had really understood the workings of the private gun trade, they would have realised what they had before them was what might be described collectively as a large and versatile factory system. Admittedly the production processes were widely spread throughout Birmingham and London, but the overhead costs were relatively low and not borne by "Ordnance". This "factory" had certain advantages over the machine intensive plant which would eventually be installed at Enfield. Firstly its manufacturing processes were not locked into producing only one type of weapon in volume, as Enfield would effectively be. Due to its heterogeneous nature the private trade had the ability to satisfy different markets with different grades of weapons, sub-assemblies, and parts, all at the same time. Because of this flexible approach, and despite the level of complaint from "Ordnance", the private sector remained the most reliable and effective supplier of small arms to the Board until 1859, only reducing deliveries of military weapons when the Enfield factory came fully on-stream in 1857. .19.

Reading the well documented evidence of the many witnesses called before the 1854 Select Committee on Small Arms, and taking into account the previous accusations of "Ordnance" that the private gun trade had acted in combination against them, it would be difficult to accept, if the evidence is viewed objectively, that the problems of poor quality and supply was wholly a one-sided affair. There is sufficient information provided from a good cross-section of witnesses who were interrogated in depth for the researcher to form the opinion that the private gun trade had been treated rather shabbily by the Board of Ordnance. However, if one reads only the critical reports from "Ordnance" members, and accepts, in isolation, the failure of contractors to meet completion dates, then it will not be too difficult to understand why the private gun trade has been held in such low esteem by some for so long.

In recent times the poor image has been perpetuated by Nathan Rosenberg, perhaps inadvertently, when he quoted from a section of Joseph Wood's memorandum (February 1854) relating to arms "...of an inferior description". The arms to which Wood refers, inter alia, is the India pattern musket supplied to the British Army during the Peninsula Wars. Although Rosenberg acknowledges that at the time when this weapon was supplied there was a "rapid growth in the output of military firearms", he suggests that this was "achieved in part by a relaxation of standards of quality". .20. Whether the "rapid growth" alluded to by Rosenberg had been achieved by the deliberate "relaxation of standards" is not clear. The information contained within Wood's memorandum covers a period of over half a century and the point relating to quality and acquisition of arms is quite general and refers also to weapons purchased from abroad. However, what is clear is that the Birmingham gun trade alone was able to average a grand total of 158,484 muskets, rifles, carbines and pistols per annum for the Board of Ordnance throughout an eleven year period between 1804 to 1815. During this time Birmingham also manufactured some 3,037,644 barrels and 2,879,203 locks for setting up into arms by the London gun trade for Board of Ordnance contracts. Also there was an estimated 1,000,000 sets of material produced for the London trade to set up into arms for the East India Company and in excess of 500,000 fowling pieces manufactured, all during the same period. .21. Considering the reliance upon mainly manual methods of production, and all the other problems alluded to above, the private sector's achievements can be viewed as outstanding.

The "factory" concept of out-working within the private sector, which can be viewed as a "collective industry" was not quite as archaic as it might first appear. While certainly there were difficulties for the private sector in the way "Ordnance" organised the system of view, nevertheless by the 1840s the London and Birmingham trades had easy access to each other through the rapidly expanding railway network. This effectively brought together and improved communication between the more distant assortment of typically small, yet diverse component manufacturers. John Dent Goodman, the respected Birmingham manufacturer and writer, lists the chief branches of these as "Stock, barrel, lock, furniture, and oddwork making; and for military guns there are in addition, bayonet, sight, and rammer". .22. While it is generally accepted that the private sector relied mainly on manual methods for the manufacture of the lock and stock, from early in the century the barrel making branch of the industry had invested in machinery. Goodman reports, "Barrel making is quite a distinct trade. For the manufacture of military barrels, a somewhat large plant of rolling, boring, and grinding machinery is required." .23.

Taking the earlier quoted figures for the private gun trade in Birmingham alone between the years 1802 and 1814, Goodman makes the somewhat chauvinistic point that "upwards of 200,000" more arms for the British Government were produced when comparisons were made with the combined output of the ten national manufactories of France. He further suggests that during this period, Birmingham turned out "500,000 to 600,000" more barrels and locks than the same French manufacturers. .24. Without this quite outstanding manufacturing commitment by the British private sector in the face of growing "Ordnance" criticism, achieved under the gathering cloud of a poor supplier contractor relationship, it is doubtful if Wellington would have been victorious over Napoleon.

Throughout the period of the Napoleonic Wars "Ordnance" made only a minute contribution to weapon manufacture. The barrel and lock factory at Lewisham, which began production in 1807, fell woefully short of its expected target of 50,000 barrels per annum. Beset by failing water power, production was eventually transferred to the newly constructed, although rather modest, Government manufactory at Enfield Lock. The factory and its workers cottages were not completed until 1816. This meant the artisans took no part in providing military small arms for the war with France. .25.

Understanding the supply background

The build up of friction between the Board of Ordnance and the private sector over allegations of poor quality products, and the failure of gunsmiths to meet contractual obligations, had reached critical proportions by the 1850s. However, the private gun trade countered and complained bitterly about the strictness of the view imposed by "Ordnance", which in the eyes of many contractors was "vexatious" and quite unnecessary. "Ordnance" were seen to be uncompromising, constantly imposing financial penalties upon the gun makers for late delivery; and non payment for parts which failed the view was a common occurrence. There were criticisms by "Ordnance" over the quality of finished parts, the allegation being that the gun trade placed too much reliance on individual sub-contractors who employed low standard workmen who would toil for the lowest wage. There were further complaints aimed at the trade's slowness and apparent reluctance to invest in modern machinery. While some complaints against the gun trade were probably justified, research has shown that the overall picture as painted by "Ordnance" seems to have come from the brush of an impressionist artist.

The nature of the contract system as operated by "Ordnance" had changed by the early 1850s from a list of approved suppliers to one of open tender. Suppliers who tendered had to put up with a system which was price competitive, with contracts that were short term. Implementation of the new contract system did not help the gun trade maintain a stable work-force as masters laid off skilled workers when business was lost or slack. This, as we have learned from Select Committee reports, helped exacerbate insecurity within the private sector. Further problems for the private sector occurred during the inter-war years due to the lack of "Ordnance" orders. This was partly due to the high levels of arms in store long after the cessation of hostilities between Britain and France. Putting all the above factors together, it is not difficult to understand why it was the private sector rather than the public which took the brunt of the industrial down-turn, with skill losses as craftsmen were forced to find work elsewhere, in some cases never to return to the trade again.

To a large extent, this was the situation in which the industry found itself when George Lovell took up the post of Inspector of Small Arms in 1840. From this period to the mid 1850s there were gathering complaints by "Ordnance" over the seeming inability of the private gun trade to meet order schedules. There was also a growing mistrust of the trade's willingness to produce reasonably priced military small arms and parts, with accusations of firms operating cartels. Certainly this was the view of a number of "Ordnance" officials who, in fairness, probably lacked the overall experience and vision to know what was required when it came to administering contracts at grass root level. This observation is supported by the fact that it took an independent Select Committee to identify the problems of contractors not being supplied with specialist equipment to check their work prior to submission to the "Ordnance" viewing houses. While it is not denied that the private contractors had joined trade associations and discussed matters of mutual interest, the "Ordnance" policy of not issuing long term contracts or guaranteeing follow-up work, would of necessity have forced prices upward as the independent trade had little other opportunity of recovering the costs of setting-up and material losses incurred through the high rate of product and component rejection. However, in contrast, it is interesting to note that Colonel Bonner of the East India Company had not complained that he had experienced a cartel operating against him.

On balance, who was to blame for supply failures?

From the continuing allegations of "Ordnance" over the failure of the private gun trade to regularly meet delivery schedules and pass the view, it would be a simple matter to assume that the fault was always with the contractor. However, the evidence would suggest that these allegations should not be taken as a wholly one-sided affair. Reading the correspondence between the private gun makers and the Board of Ordnance (much of which is engrossed and included within the appendix to the report of the Select Committee on Small Arms 1854) and studying the evidence given before the Committee has allowed an insight into the difficulties experienced by both "Ordnance" and the private sector. Here we have clear indicators which show that the private gun makers were not always to blame for the poor quality and late delivery of which they were accused by "Ordnance". To illustrate the point, it is worth examining extracts from the evidence of masters, workmen and experts who came before the Select Committee of 1854. The Committee had been appointed with a prime objective to "consider the Cheapest, most Expeditious, and most Efficient Mode of providing Small Arms for Her Majesty's Service". .26. Although the Committee were finally to recommend to Parliament "...that a manufactory of Small Arms under the Board of Ordnance should be tried to a limited extent. This manufactory would serve as an experiment of the advantages to be derived from the more extensive application of machinery, as a check upon the price of contractors and as a resource in time of emergency...". The Committee made it clear that "...the system for the contracting for the supply of Small Arms should not be discontinued...". They further recommended that the Enfield factory should be expanded to accommodate their plan for the increased use of machinery. .27.

In achieving their objective, the Committee had to investigate very thoroughly the complaints of the Board of Ordnance over the difficulty of procuring sufficient numbers of small arms on time and made to a particular quality and standard. On the other hand, to be objective, the Committee had seriously to address the many criticisms made by the private contractors over the Board's strictness of view. This the trade alleged had prompted delays in delivery and, in some cases, non fulfilment of contracts. The witnesses called to give evidence before the Committee were subjected to very close scrutiny. The procedures adopted were not too dissimilar from a cross-examination in a court of law. Making a careful study of the questions and replies allows a greater awareness of the problems surrounding the gun trade. This helps to bring about a more balanced view which enhances our understanding of the difficulties which the "Ordnance" contractors experienced.

Joseph Brazier, a prominent Wolverhampton lock manufacturer, who had been making locks for the Board of Ordnance since 1836 had not continued to be a contractor after 1850. In evidence he explained that the "Tower at Birmingham" had rejected a new musket lock of his and he was unable to discover the reason why. Brazier even produced the lock before the Committee and challenged any member to pass an opinion. During questioning it was learned that Brazier had exhibited this very lock at the Great Exhibition of 1851, for which he had received a prize. Brazier stated "The lock was looked at by the commissioners appointed by Government from Belgium and France, and Mr Lovell was there also". The question was then put, "Mr Lovell was one of the commissioners, was he not"? To this Brazier replied, "Yes". .28. This must have given Brazier great satisfaction as his evidence shows he attributed the strictness of view solely to George Lovell. In reply to the question "Has there been any improvement in the view during the last month?" Brazier answered, "They are not so strict; they were aware of this investigation, and that has put a check upon them, I suppose". In reply to the next question, "Since when have they ceased to be so strict?" "Since Mr Lovell's indisposition" came the response. .29.

Brazier was asked further questions about why complaints were not generally made about the viewer. This was said to be because the viewers would "punish them for it". It was explained to the Committee that the method of view was by jig and gauge. Brazier produced a gauge for them to see, suggesting it was identical to those used by the viewers. When a part was rejected by the viewer it was customary to identify the problem area with a chalk mark. Even after these measures, it was suggested, on many occasions the contractor was still unable to discover the reason for rejection. If an explanation was sought from "Ordnance" often no new information was forthcoming. From the evidence it can be discovered that many parts were rejected on the basis of what the viewer perceived to be questionable finish and not because the piece failed the gauge test, these judgements being purely subjective and having no bearing on the mechanical working of a particular mechanism or part.

When questioned further, Brazier revealed there were different qualities of lock which were price dependent. His locks tended to cost in the order of thirty shillings each, while the current contract lock was eight shillings and three pence. The point was therefore put to Brazier, "Does not the price at which it is possible to produce the Government lock depend on the view?" To which Brazier replied, "Yes, it depends upon the view as a matter of course". The questioner then concluded, "If the view is too strict, it would not be possible to produce it at the price?" It cannot be", Brazier replied. Staying with the point, the questioner confirmed, "In short, the possible production at the price depends upon the view?" "Yes"; came the response from Brazier. .30. From this very crucial piece of evidence it would appear that "Ordnance" would have had extreme difficulty in getting any locks past the viewer if they insisted upon a high level of finish for the lowest price. It would seem the only sensible way for the Board of Ordnance to break out of this "endless loop" would be by accepting mechanically functional and correctly dimensioned locks, with a lower standard of finish than they had hitherto set. Presumably this was the way in which the East India Company was able to obtain satisfactory quantities of serviceable weapons.

In answering the question "What do you think has been the cause of the delay in producing arms, which is complained of by the Board of Ordnance?" William Scott, a Birmingham gun maker who had been in the trade some thirty years, and had previously worked as an "Ordnance" viewer, gave the opinion that it was because manufactories were having to close due to lack of orders from the Board. As an example, he explained that "since 1851, I, amongst others, have had nothing at all to do for my men; the vices, the benches, the machinery, and the rifling machines are lying idle". He then went on to say "I have seen men often about the London Docks and wharves, scores of them, almost shoeless and stockingless, and in a state of destitution and starving, and seeking labour and occupation elsewhere". .31.

While Scott's experiences are not directly related to the strictness of view, it will be obvious that if skilled men are lost to the trade, or at best return after a period of lay-off, then the standard of workmanship will generally not be the same as that where craftsmen have been continually employed. Until such times as the artisan can once more regain confidence in his ability to work accurately and fast the standard of workmanship will in general be below his best. So it can be seen that if a government lacks a well thought out strategy for the arms industry, on which it relies for its supply of military weapons, taking into consideration such aspects as continuity of orders, fairness of inspection and good communication, then indirectly the standards of quality and delivery will be influenced by default. Scott had identified the problems of a weapon procurement system which was not designed to place regular long term orders on its suppliers. The reasons for this were probably due to a combination of ignorance on behalf of some members of the Board in not having a clear understanding of manufacturing requirements, and political pressure created by the private sector to limit "Ordnance" encroachment into their area of livelihood.

Of course it could be argued that if "Ordnance" had an understanding of manufacturing needs and the will to work amicably with the private sector, the difficulties encountered by both sides would not have arisen. However, with the technical and structural problems identified by Brazier and Scott, it would have been almost impossible for military gun making in the private sector to develop efficiently and to prosper. That was unless Government adopted a consensus strategy with the gun makers, similar to that operated by the East India Company. By 1854, with war looming in the Crimea, any idea of such a policy materialising from a Government initiative would have passed into obscurity.

John Stephenson, a lock filer who now resided in Birmingham, had previously worked at the RSAF, Enfield. He explained to the Committee that he had a contract in November 1851 with the Board of Ordnance for hardening and freeing 10,000 sears and tumblers. Unfortunately he had been unable to get any of his work past the "Ordnance" viewers and he had now left this branch of the industry. Stephenson had contracted to do the work at seven shillings per 100, when he had previously been paid twenty-five shillings per 100. Even then he stated that he "could have got a living at it if they had been looked at as they were when they were 25s. a hundred". Stephenson informed the Committee that he had been a lock filer for 17 years. The work, he explained, which had recently been rejected, was similar to that undertaken during his time at Enfield which had passed inspection without any problems. When asked, "was anything said to you about the difference in the price?" Stephenson replied, "Yes, there was an item made in Mr Lovell's office, and he said it was a most awful price". Reading through Stephenson's evidence, a rather ironic story emerges. He had only completed 150 pieces of his contract, all of which he was unable to get past the viewer. In his words, "I let them lie for some time, and sold them to another contractor, and he sent them in, and I heard no more of them". .32.

From this evidence it is possible to offer two probable causes which might have accounted for the viewer's rejections, providing the assumption is made that Stephenson's work had not deteriorated in any way since he left Enfield.

(a) There was a difference in viewing standards operating between Birmingham and Enfield.

(b) The strictness of view had increased in the period between Stephenson getting 25s. per 100, to when he contracted to the Board for 7s. per 100.

Considering the evidence, it would appear on balance that the two proposed reasons for rejection probably carry similar weight. For example, Brazier was of the firm belief that different standards of view were operating between Birmingham and Enfield. He cited an incident to the Committee concerning a particular consignment of gun locks which had been rejected, he explained, "...they sent them back at Birmingham when they did not do so at Enfield". .33.

Interestingly there was the distinct possibility that reason (b) was operating against Stephenson. Brazier in his evidence had alluded to the "view" being "much more strict" after the open tendering system "made its appearance" in 1849 (it will be recalled that Wood gave the date for the introduction as March 1850). .34. Under the circumstances, and given this latter fact, it would have been logical for "Ordnance" to impose a tighter level of inspection to ensure that standards of workmanship by any new contractor did not further compromise quality. This could have accounted for the difficulty experienced by Stephenson.

George Lovell, in a letter dated December 1848, had recommended to the Board, inter alia, that "The Board's List of Tradesmen" be scrapped and that "tenders should be called for by public advertisement, ...and that such selection will be governed solely by reference to the lowest price offered, and by consideration of the capabilities of the parties to fulfil their contracts." .35. This clear recommendation by Lovell, and Brazier's evidence to the Committee, would suggest that the system of open tendering had been implemented, further confirming Brazier's allegation of the view becoming "much more strict". With the contracting system being thrown open to all and sundry, and Lovell stating that acceptance would be "governed solely by reference to the lowest price offered", "Ordnance" would have had little option but to tighten its inspection procedures to make sure that lower prices did not equate to lower standards.

While the precise reasons behind the rejection of Brazier's and Stephenson's work, with its subsequent alleged acceptance when sent to Enfield or passed on through another contractor, may never be known, it is difficult to believe that these incidents were unique or would have passed unnoticed. In the atmosphere of distrust and suspicion which existed in the private sector, Brazier's and Stephenson's stories would have, no doubt, gained credence as they circulated within the gun trade, helping to convince the contractors that "Ordnance" was operating unequal inspecting standards in different viewing departments. With the bulk of British military weapons being manufactured in the Birmingham district and the procurement system having changed to open tender at the "lowest price", it is conceivable that the Birmingham viewers might have been more severe with their level of inspection than Enfield. There is also the fact that George Lovell took up residence in Birmingham in the autumn of 1852 to fulfil the duties of Assistant Inspector. This may have increased pressure on the local viewers to apply a stricter standard of inspection. .36.

Functionality or finish?

The evidence given to the Committee by John Barnett, a prominent London gun maker whose family had been a contractor to the Board of Ordnance since 1794 was seriously to challenge the "Ordnance" notion that the fault of quality and late delivery lay mainly with the private sector. Barnett explained he had not had an order from the Board since 1849 and had to rely on orders from "merchants and foreign parts". He stated that in 1852 he had made "repeated applications", both personally and by letter, to the Board of Ordnance for part of a contract which he had heard was being issued to the Birmingham gun trade. In his words "I begged that the Board would give a portion to London, and I offered to take them at a price which I afterwards found was lower than they issued to Birmingham for". .37. Apart from obviously wanting the business, it does appear from the evidence that Barnett was desperately trying to secure work to keep his men employed. In an attempt to ensure the survival of his business, Barnett had secured orders over the years with North America, the East India Company and the Hudson Bay Company. By a strange twist of fate the orders for the latter have given the writer the opportunity to question further the methods of view employed by the Board of Ordnance. It so happened that, at the time of the Select Committee's investigations, Barnett had a legal action pending in Belgium over what was a blatant case of forgery. This was revealed in Barnett's answer to a question concerning the sale of Belgian arms to the Hudson Bay Company, "Do they buy any in Liege?" - "No; the Belgians only copy that gun, the English gun, and put my name on it; and the Belgians, to a very great extent, send them out to New York. That is one of the guns that I have an action pending now about; the gun sent to America". A further question followed, "They put your name on it to give the gun a better character?" - "Yes; not only the name, but the address, and they imitate every mark; they are exceedingly clever at that". .38.

From this last piece of evidence it would seem reasonable to conclude that John Barnett's company was capable of making arms to a sufficiently high standard that others wished to jump on the band-wagon of his success by making copies. If one was taking a sceptical view point, it might be argued that the Belgium gun makers were only putting Barnett's identification on their arms to command a higher price, which we know from the evidence Barnett was able to get. However, if this particular conclusion is drawn, then one should acknowledge that the quality and finish of Barnett's weapons must have been universally known and therefore perfectly acceptable to the Belgian gun maker's customers. The corollary to this would be to conclude illogically that a higher price would have been paid for an inferior weapon.

This example of Barnett raises a further question regarding the private sector. How was it, if the standard of manufacture was so poor, that the Birmingham and London gun makers were able successfully to supply arms in quantity to customers other than the Board of Ordnance, seemingly without high levels of rejects? The facts are, as the evidence shows, that although the private gun trade did have rejects from the non "Ordnance" trade, the bulk of the problems seem to have been confined to barrels and locks. In the case of John Barnett's company, he suggested that, out of a total of 105,000 complete arms made for the East India Company he had experienced a reject rate of between 15 and 25 per cent before and after proof of barrels, which incidentally were made in Birmingham, and a figure of 10 to 15 per cent for the locks. Even given these relatively high rates of component rejects, the London gun trade alone was able to deliver the following quantities of arms between 1841 and 1850:-

Date.	East India Company.	Government.	Total.
1841	20,150	7,660	27,810
1842	36,353	12,926	49,279
1843	34,880	12,270	47,150
1844	25,362	13,496	38,858
1845	49,623	12,539	62,162
1846	50,880	16,336	67,216
1847	57,214	18,376	75,592
1848	55,068	23,862	78,930
1849	71,381	26,366	97,747
1850	26,025	13,607	39,632
	426,936	157,440	584,376

It will therefore be seen, that the London trade over a period of nine years was supplying almost three guns to the East India Company to every one supplied to "Ordnance". Also it should be remembered that these figures are exclusive of supplies to foreign governments and the commercial trade generally. In fact, Barnett was confident that "Under proper management, the productive power of the London gun trade alone for Military Arms is 100,000 per annum; while the trade of Birmingham is capable of furnishing, with ease, a similar amount". .39.

An independent assessment

It has been shown that the private gun trade was capable of producing large quantities of arms mainly by manual methods, there being a general reluctance amongst the gunmakers to invest in costly capital equipment. Without an "Ordnance" system that supported the principle of issuing long term contracts, it is difficult to see how the trade's attitude might change. However the strictness of view, which was felt to be so unreasonable by the private sector, the nature of contracts and the reluctance of the Board of Ordnance to issue patterns and gauges (this will be addressed when examining the role of Lovell in the following chapter), had not gone entirely unnoticed by the Select Committee on Small Arms. In their report to Parliament dated 12th May 1854 they were to state:-

> With a view of expediting supplies, and giving confidence to the trade, Your Committee recommend that contracts should only be entered into with such men as have means and capital to fulfil engagements; that in future the contract should be understood to commence from the time of the delivery of the pattern; and that in all cases of doubt on the part of the viewer, or remonstrance on the part of the contractor, a ready appeal to a competent person should be afforded. .40.

The Committee also took the opportunity to point out that, in their view, while recognizing the contractor's need for continuous orders to stop skilled workmen drifting away from the industry in slack times, they were in general against the principle. It was argued that if contracts had been placed for periods of three years or more, then "...in this age of rapid invention, such a course might be attended with very inconvenient consequences". As an example, they referred to the change of pattern from the 1851 rifle to that of the 1853, suggesting that had long term contracts been in operation then "Ordnance" would have been supplied with a large quantity of out of date arms. .41. This might suggest that financial penalty clauses were not in operation at the time for cancelled orders or perhaps "Ordnance" did not wish to enter into this kind of agreement.

While it is not appropriate to deal with the arguments of "rapid invention" here, it is worth remembering that a factory is usually unable to cope efficiently with hasty product changes. These invariably lead to loss of production volume until experience of manufacturing the new article is gained. Initially this might result in poor quality products, as the workforce go through a learning phase before the required standards are reached. It would also seem reasonable to conclude that the uncertainty which would have been caused by a period of "rapid invention" was yet another factor which confronted the private gun trade, furthering their reluctance to invest in increased levels of new machinery. If the trade had opted for higher levels of mechanisation over the traditional methods of production, it could be argued that they would have lost the advantage of flexibility in the event of frequent model changes. Also, by adopting dedicated machine production methods it would have made it more difficult to manufacture their three main weapon categories, sporting, African and military.

There is of course a further consideration for the private sector, which is that it is not always the first company to install the latest technology which benefits in the longer term. It has often proved better to leave a period of time to allow the technology to stabilise before the decision is taken to install the latest plant and equipment. This point has been made in Chapter four in relation to the competitors of the British television industry, when it was argued that a waiting strategy can often bring about economic and cost benefits.

What emerges from the research into the strictness of view is that the Board of Ordnance appeared to be demanding standards which the gun trade could not consistently meet, particularly that of finish, until George Lovell was replaced by Gunner. It also seems remarkable from the evidence that, if one excludes "Ordnance", the customer did not generally want arms manufactured to such a high standard of finish. This was particularly true in the case of the East India Company who were looking for functional replacement weapons, with the minimum amount of design change, at a reasonable price.

To support this view it is worth examining a report dated 6th August 1839 written by Colonel Bonner. This document highlights an extremely important point concerning the private gun trade which hitherto seems to have gone unnoticed. That is, even if "Ordnance" had the capacity to manufacture large quantities of small arms, it could not be sufficiently flexible to meet efficiently the individual requirements of a section of the widespread military market (as Bonner would have wanted).

Bonner's report is addressed to the Honourable Political and Military Committee and sets out, inter alia, his objections to taking quantities of new arms fitted with percussion caps. From the evidence it is clear that Bonner had already studied reports of the superiority of the cap over the earlier flint lock and had accepted that it was infinitely more reliable. He went on to say "I hope I shall not be deemed presumptuous in offering an opinion somewhat at variance with that recognized with the Board". Bonner complained that the new pattern muskets had "a heart stock instead of the usual and less expensive description, both the interior and exterior of the barrel have a finish beyond what is given or is necessary to be given to military arms - it is provided with a double sight, flat bolts, box trigger, and Ram-rod and Bayonet springs and the cost is stated to be £3:12:1/2". What Bonner was really objecting to was changes to design and price, since he stated that the cost is "much beyond what has ever been paid for a musket". Going on, Bonner explained that as far as the Indian Army were concerned, he could provide modifications which in his opinion would cost far less than what was on offer from "Ordnance". He further suggested that there were no problems with the current East India barrel regarding "strength and correctness of bore and requires no improvement". With regard to his suggested modifications he wrote:-

> I have therefore in the musket No.4 applied the percussion principle of the Ordnance Pattern - substituting round bolts for the flat bolts of the Ordnance and for the wire pins heretofore in use: with these exceptions it is the existing pattern of the Company's musket. The lock is the same in principle, workmanship and value as that of the Ordnance - but I have made some alterations in the screws and tumbler pin, which I consider improvements". .42.

Bonner also stated that he had "not applied the double sight, box trigger, bayonet spring, or new ramrod spring, as I consider them unnecessary and I have retained the present pattern bayonet". In concluding his report Bonner remarked:-

> With regard to the stock, I am clearly of the opinion, that although a Hart stock may improve the appearance of the musket, its exclusive adoption is neither necessary or desirable - The difference of expense is considerable and great difficulty would be experienced, particularly in the event of war, in obtaining them in any quantity. I am the more satisfied of what is technically termed Sap Stocks (that is stocks cut indiscriminately from the Plank) from an examination of upwards of 100 muskets recently brought from India by invalids bearing dates from 1808 to 1816 - not one of

> these have heart stocks, yet after a period of service, of from 23 to 31 years they are perfectly sound and exhibit no tendency to decay. .43.

By Bonner's clear evaluation of the weapon from the perspective of the customer, it can be seen that the interests of the East India Company were not being served. Had "Ordnance" wished to take over the role of supplier of military weapons, then they had clearly got this customer's requirements wrong. Bonner had demonstrated that from the East India Company's stand-point, the product had been over engineered in both specification and finish. Therefore it did not meet the criteria of the army in India who were clearly looking for a straightforward and reliable weapon.

The report illustrates that, during the first half of the century, the requirements of the British armed forces, as perceived by "Ordnance", were quite different from those of other large consumers like the East India Company. This would suggest that it was highly unlikely that "Ordnance" could or would fulfil, in the same way, the role of the private sector. This branch of the gun trade was capable of manufacturing military weapons to suit differing customer requirements. The key strength of the private sector was its heterogeneous structure which allowed them to manufacture weapons flexibly without being constrained by a rigid factory system. Until internationally the military market accepted a standard type weapon, it could be argued that the labour intensive nature of the private sector was a key factor in its own survival.

A different approach

The report of the 1854 Select Committee, probably for the first time, formally recorded a somewhat different and more amicable method of dealing with the private gun trade when it revealed how Colonel Bonner purchased arms on behalf of the East India Company for its regular army of over 200,000 men. While the Committee, in its final recommendations, pointed out that the East India Company as well as the Board of Ordnance "provide only one pattern of the articles for contract", they did however suggest that "...there seems no reason why a larger number should not be provided if by this means the operations of the contractors could be saved from needless delay". The Committee were clearly impressed by Bonner's method of procuring small arms which they summarised in the following detail:-

> Colonel Bonner described to Your Committee the system under which Small Arms were procured by the East India Company. They have a list of contractors for setting up and making the materials of muskets. The smaller articles, such as screws, nails, and swivels, together with the stocks, are provided by the setters up. Each of the other parts of the musket is got directly from the persons whose trade is to manufacture it. When a supply of muskets is required by the Company, Colonel Bonner ascertains the Ordnance prices, and calls together the setters-up and material makers. He shows them the pattern gun, and discusses with them the price. The price is then fixed by discussion and arrangement, and not by competition. .44.

It is perhaps the last sentence of the summary which gives the true meaning and allows us to understand more fully Bonner's method of dealing with the private sector. With references to "discussion and arrangement" and "not by competition", it can be seen how his methods of procurement differed radically from that of "Ordnance".

A labour intensive industry without incentive to change

The respected "Ordnance" engineer John Anderson had been sent in March 1853 with Lieutenant Warlow, Royal Artillery, on a fact finding tour of British manufacturers associated with the forging of wrought iron. As the tour embraced Birmingham, Warlow, accompanied by Anderson, took the opportunity to call upon some of the gun makers he was acquainted with as a matter of courtesy. On returning to Woolwich, Anderson produced a report covering the whole tour, within which he was able to provide a unique glimpse of mid century small arms industry in Birmingham from the perspective of a respected engineer. He describes the status of the trade thus. "We then visited a number of establishments engaged in military musket and bayonet work, all of which, however, are in a low mechanical state, and at least 50 years behind most of the other branches of manufacturing industry which we have been examining." .45. Anderson lists these other branches of manufacturing as "...cotton, flax, and woollen trades, engineering and machine making, the tool makers of Leeds and Manchester, steel pen and wood screw making of Birmingham. Those we were very much pleased with." .46. Two interesting observations emerge from Anderson's report in connection with the Birmingham gun trade. Firstly, he comments on the backwardness of the industry with regard to the lack of machinery employed in weapon production, but makes no comment on the skill of the workmen or the quality of the product, apart from mentioning the "great waste" of the out-work system with parts being carried from the profusion of workshops to the setter-up. This Anderson compared to the efficiency of the flow-line process he had proposed for Enfield, with self-acting machines where "...everything connected with it passing consecutively on from one stage to another, never passing over the same ground twice, so that the raw materials which go in at one side shall come out a finished musket at the other". .47.

Anderson's report, with his observations of the Birmingham gun trade, may simply have been a case of him publicising his strongly held views. He was a committed machine enthusiast with an exceptional record of inventing and modifying. It is known that he had been responsible for devising and introducing new mechanical manufacturing processes at Woolwich Arsenal. .48. Nevertheless, the fact that he had not commented on the Birmingham workforce or the product might suggest that what he had witnessed of the manual system of manufacture did not strike him as being unduly odd or slovenly, perhaps no less than an engineer of his calibre would have expected, given the way the industry was structured. If Anderson had encountered poor standards of workmanship to the levels implied by "Ordnance" and some later commentators, then it would seem reasonable to assume that he would have mentioned the fact in his report. After all, he did see fit to comment that the gun trade was "50 years behind most of the other branches of manufacturing industry". Secondly, and even more interestingly, the industries which were mechanised and up to date, which he was "pleased with", do not appear to have any direct links with "Ordnance" and small arms contracts. Perhaps there is a subtle lesson to be learned here. The suggestion being, that if you are a company in the private sector wishing to do business with "Ordnance", then it would seem wise to negotiate a contract with mutual terms and conditions of trading, in a similar way to Bonner for the East India Company.

The first signs of an atmosphere of normality descending upon the private sector can be detected from the evidence given before the 1854 Select Committee, when several of the old established contractors began to experience less severe viewing standards when R W Gunner accepted responsibility for the "Ordnance" office in Birmingham after Lovell's health began to fail in 1853. This was not a case of contractors now being able to turn in shoddy work, they still had to comply with "Ordnance" inspection standards, but it would appear that a mutually agreeable common sense approach was starting to develop. An example of this emerges from the evidence given by Brazier when he described what he considered to be a good functional gun lock. Under questioning, Brazier wholeheartedly agreed that if a lock sent to "Ordnance" "did not meet all the requirements of the gauge" it should be rejected. However, he did make the point that it should not "fit the gauge to a hair's breadth", as in his considered opinion "it cannot be better or worse for it". .49. This would seem to be a perfectly reasonable position to adopt under the system of out-work which employed mainly manual methods of manufacture. After all, it would not have been possible under such an arrangement to supply large quantities of weapons made to close tolerance at prices attractive to "Ordnance". The exactness, repeatability and interchangeability of machine intensive manufacture could not be expected from men filing to gauge.

Support for Brazier from the 20th century

Using a set of the pattern 1853 rifle gauges belonging to the Ministry of Defence Pattern Room, Nottingham to measure the dimensions of a 19th century Birmingham gun lock revealed a minutely raised surface on the lock's bridle. This area of raised metal had been caused by the viewer stamping his pass mark on the part, so that the bridle, which we know from the viewer's stamp had already passed inspection, was made to fail the gauge test retrospectively. This interesting and highly significant discovery adds further authenticity to the documentary evidence of witnesses like Brazier recorded in the Select Committee Reports and supports the private sector's claims that "Ordnance" were operating too tight an inspection criterion. The gun lock in question was still operating perfectly over 120 years after manufacture, the viewer's mark having been stamped in an area of the bridle which was in free air and had no detrimental effect whatsoever on the function of the mechanism. Of course it could be argued that the viewer placing his mark on a surface which remained in free air was a deliberate act. However, the point being made is this. If the bridle dimension when originally gauged had measured to the minutely increased width caused by the viewer's stamp, then the "Ordnance" inspector would have had little option but to reject it as failing the test. Here we have a classic example of a standard being set and applied without taking account of the function or physical position of the part in question. Even if the bridle had been one or two thousandths of an inch thicker it could not in any way have affected the part's ability to function correctly and it would have made no difference whatsoever to its interchangeability with other like components. It is not often that one is fortunate to discover such a good example of physical evidence which supports the interpretation of data obtained from documentation, suggesting that "Ordnance" were in fact applying too strict a standard of inspection.

The discovery would also support the notion that "Ordnance" viewers were not allowed to exercise individual discretion; the part either fitted the gauge or it did not. While measurement by a gauge was precise and left little room for doubt, the viewer's judgement of finish, by its very nature, was subjective and open to challenge. However, it will be recalled from the evidence obtained from the Select Committee Reports that there was a slightly more relaxed approach to viewing when Gunner took over the responsibility of inspection from Lovell. This might have meant the acceptance of a bridle which was marginally over gauge. Unfortunately one can only speculate on the possible outcome, as the opportunity to prove this point has probably been lost with the passing of time and the difficulty of obtaining authentic samples which could be identified as being manufactured after Gunner took over.

NOTES

.1. House of Lords Record Office, London.
Memorandum from Secretary, War Office, J. Wood, 18th February 1854. Included under, Appendix to Report from the Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, pp.451-452 (489-490)

.2. Birmingham Proof House Library, Young, D W, "History of the Birmingham Gun Trade up to Mid 1935", Unpublished document, No.19 (Birmingham, 1936)

.3. Public Record Office, Kew.
Letter to J Wood, Office of Ordnance, from Hollis & Sheath, 12/9/1854. Reference WO 44/701

.4. Public Record Office, Kew.
Letter to J Wood, Office of Ordnance, from Hollis & Sheath, 16/11/1854. Reference WO 44/701

.5. Public Record Office, Kew.
Letter from R W Gunner, to Board of Ordnance, 22/11/1854. Reference WO 44/701

.6. Public Record Office, Kew.
Letter from R W Gunner, to to J Wood, Office of Ordnance, 31/3/1855. Reference WO 44/701

.7. Op.cit., Wood, memorandum 18th February 1854

.8. Bailey, De Witt, "George Lovell and the Growth of the RSAF Enfield", paper presented at MA Day School, Middlesex University, 4th July 1992, p.6

.9. House of Lords Record Office, London.
Examination of Colonel J G Bonner, 31st March 1854, Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.361

.10. Ibid., pp.361-365

.11. Ibid., pp.361-362

.12. Op.cit., Wood, memorandum 18th February 1854

.13. Op.cit., Bonner, p.361

.14. Bailey, De Witt, "Development of the British Ordnance Musket Lock-part 2", International Arms and Militaria, No.2 Quarterly, p13

.15. Op.cit., Bonner, p.361

.16. Goodman, John D, "The Birmingham Gun Trade", Samuel Timmins Ed. Industrial History of Birmingham and the Midland Hardware District, Robert Hardwick, London (1866) p.388

.17. Op.cit., Wood, memorandum 18th February 1854

.18. Op.cit., Goodman, pp.419-428

.19. Ministry of Defence Pattern Room, Nottingham. Roberts, G H, "History of the RSAF Enfield Lock", Unpublished manuscript, p.C10

.20. Rosenberg, Nathan, The American System of Manufacturers, Edinburgh University Press, (Edinburgh, 1969) p.38

.21. Op.cit., Goodman, pp.412-413

.22. Ibid., pp.388-389

.23. Ibid., pp.388-389
Also see Op.cit., Goodman, pp.388-389, and Examination of Richard Prosser, 21st March 1854, Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, pp.172-174
According to Goodman, military barrels were made by a rolling process. The barrel started life as a piece of iron measuring 12 x 5.5 inches and 0.5 inches thick which was first turned in a pair of grooved rolls until the edges met. The piece was then brought to welding heat in a furnace and "closed in a third groove of the roll". Subsequently the piece was heated again then "passed through a succession of grooves on a mandril until the 12 inch tube is drawn out to the required length of about 40 inches". The invention of barrel rolling machinery has been credited to Osborne, a Birmingham manufacturer, in 1817.
Because up to 25% of barrels could be lost in the proof and barrels for a range of weapons could be accommodated relatively simply on one machine, it would seem that these were important factors in determining the early mechanisation of this branch of the gun trade in Britain. The lock mechanism comprising of typically 12 separate parts could not be accommodated on one machine, neither could the irregularly shaped gun stock with its various cut-outs and holes for the lock, barrel, rammer, heel plate etc. From an industry point of view, it would have been logical to use the plentiful supply of cheap labour to manufacture these two latter items.

.24. Ibid., p.414

.25. Putnam, Tim & Weinbren, Dan, A Short History of the RSAF Enfield, Middlesex University, (Enfield 1992), pp.5-8 See also: Blackmore, Howard L, "Military Gun Manufacturing in London and the Adoption of Interchangeability" Arms Collecting, Vol. 29, No.4, November 1991, p.115

.26. House of Lords Record Office, London. Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.1

.27. Ibid., pp.10-11

.28. House of Lords Record Office, London. Examination of Mr Joseph Brazier, 24th March 1854, Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.247 (285)

.29. Ibid., p.246 (284)

.30. Ibid., p.247 (285)

.31. House of Lords Record Office, London. Examination of Mr William Scott, 24th March 1854, Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.253 (291)

.32. House of Lords Record Office, London. Examination of Mr John Stephenson, 29th March 1854, Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.319 (357)

.33. Op.cit., Brazier, p.251

.34. Ibid., p.250

.35. House of Lords Record Office, London. Letter from the Inspector of Small Arms, respecting the Disadvantages of the System pursued for obtaining Arms, George Lovell, 16th December 1848. Included under, Appendix to Report from the Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.454 (492)

.36. Op.cit., Bailey, pp.8-9

.37. House of Lords Record Office, London. Examination of Mr John Barnett, 30th March 1854, Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.339 (377)

.38. Ibid., p.339 (377)

.39. House of Lords Record Office, London. Ordnance Estimates, 30th March 1854, Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.343

.40. House of Lords Record Office, London.
Report from the Select Committee on Small Arms, 12th May 1854, Reports Committee's Vol. XV111-1854, p.10

.41. Ibid., p.10

.42. India Office Reading Room, London.
Report of Colonel Bonner, 6th August 1839.
Reference L/MIL/5/421. The reference to "musket No.4" suggests that "Ordnance" had sent the East India Company a number of sample weapons for trial and comment. Sending samples to different regiments was quite a usual occurrence within a weapon's evaluation phase.

.43. Ibid.,

.44. House of Lords Record Office, London.
Supply of the Musket, Report from the Select Committee on Small Arms, 1st March 1854, p.8

.45. House of Lords Record Office, London.
Examination of Mr John Anderson, 13th March 1854, Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.27

.46. Ibid., p.27

.47. Ibid., p.29

.48. House of Lords Record Office, London.
Examination of Mr John Anderson, 15th March 1854, Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, pp.64-65

.49. Op.cit., Brazier, p.251

LOVELL'S ROLE IN SHAPING "ORDNANCE" AND THE IMPACT ON THE PRIVATE SECTOR

Examining the role of George Lovell, looking at his relationship with, and his influence upon, the private gun contractors, particularly after he was promoted to Inspector of Small Arms in 1840, casts further light on the continuing problems experienced by Government in the procurement of sufficient quantities of good quality small arms during the first half of the nineteenth century. Lovell emerges as an exceedingly complex man, at times headstrong, with a burning desire to secure for the British soldier the best possible weapons to defend the Empire. To discover how Lovell tried to achieve this goal, and the lengths to which he was prepared to go, will require the reader to follow carefully his footsteps down an intricate path and be ready to weave and change direction as different external influences come into play.

Enfield armouries developing role and Lovell the engineer

At this point in the thesis it is worth pausing to remind ourselves of the early role of the Enfield armoury, so that Lovell can be viewed against the background of the factory's development.

Prior to the introduction of the "American system of manufactures" at Enfield Lock in the mid 1850s, the factory's role was one of assembly, repair, re-furbishment, development and testing, of a range of muskets, swords and rifles. A further part of Enfield's responsibility, that of monitoring the quality and cost of weapons supplied to "Ordnance" by the private gun trade, became considerably strengthened with the transfer of the remaining sealed patterns from the Tower of London after the devastating fire at the armoury and workshops on the night of 30th October, 1841. .1. Holding the patterns against which military arms were judged placed Enfield in a very powerful position, allowing them to determine and maintain strict standards of accuracy and finish. However, as we will learn, it was the appointment of George Lovell, the resident Storekeeper at Enfield Lock, to the position of Inspector of Small Arms in 1840, placing him in charge of all aspects in the manufacture of military weapons, which was to have a profound influence upon the development of the British military gun trade.

Significantly the position of Inspector had been re-established, which suggests that at the time, not only did the Board of Ordnance hold Lovell in high regard for his inventive and technical skills, but also that they were becoming aware of the increasing variations and gathering pace of weapon technological development. It was therefore important for "Ordnance" to ensure that this growing and evolving technology was carefully monitored and managed by experienced personnel, making Lovell, with his considerable knowledge of invention and the gun trade, the ideal candidate for the job. The fact that Lovell had spent a quarter of a century at the Enfield factory, taking him from the establishment of the plant to the perfection and development of the percussion cap, had no doubt helped his candidature. Lovell's promotion, apart from making him responsible for over-seeing the manufacture of military weapons, had effectively placed him in charge of all military small arms inspection, with responsibility for the superintendence of the "Ordnance" departments at the Tower, Birmingham, and the manufactory at Enfield. His reporting line was direct to the Master General of Ordnance, placing him in a very powerful and influential position. .2.

Lovell's appointment, as we will learn, was to become an act of mixed fortune for the British small arms industry, although at the time it is probably fair to conclude that the major changes he was to impose upon the gun trade could not have been foreseen. However, his promotion can be identified as one of the most important single factors contributing to far reaching improvements in the manufactured quality and standardisation of British military small arms, although the path to this eventual destination was paved with many hazards.

Since his appointment as Storekeeper at Enfield Lock in 1816, a position roughly akin to a factory director of today, Lovell had not only involved himself in purely organisational and operational matters but had also taken a personal and active interest in the design, development and improvement of small arms generally. He was responsible and influential in the design and development of a wide range of ordnance products, from the percussion lock system to bayonets and different forms of ammunition including experiments with various types of fulminating powder. De Witt Bailey has identified Lovell as being responsible for the design of at least twenty-five small arms, and if modifications are included he suggests this figure would be much higher. .3.

Largely under Lovell's direction a new smooth-bore musket received approval in 1841 and went into production. The model was to be known as "The Percussion Musket 1842" (Fig.4), continuing in service with the British Army until being partially succeeded by the Minie rifle in 1851 (Fig.5), which in turn was replaced by the "Enfield three-grooved Rifle" or "Rifle, musket Pattern 1853" (Fig.6). This arm had a double distinction. It was the first weapon to go into service with the British Army bearing the name "Enfield" and it was also the first musket to be manufactured in Britain using the mass production techniques of interchangeable parts under the "American system", when the new purpose built factory at Enfield Lock officially started volume production in January 1857. .4.

What views did Lovell really hold?

Lovell's former role as Storekeeper at the Government armoury at Enfield Lock had allowed him the opportunity to bring together and maintain a small group of skilled artisans. This encouraged him to hold the view that significant differences in product quality and finish existed between the "Ordnance" manufactory, which he had nurtured from its inception in 1816, and the private gun trade at large, particularly that of the Birmingham district. In April 1852 (a time approaching the end of his career) he was prompted to write:-

> At Enfield no workman is admitted unless he be of the first class in his trade, and of sober, moral, and regular habits. He has the assistance of the best machinery and works under the immediate eye of the viewer, who corrects any errors of work as they arise. He has a comfortable home, and receives his wages in full at a certain hour every week. Whereas at Birmingham, the first and ruling question is price; the man who will work at the lowest rate is entrusted with it, without much care as to capability or character; there is little or no

> tie between him and his master; he is mulcted for the mill-power that he uses and for tools, and receives his wages often very irregularly. The consequence is, that the workmanship is inferior, and the men often resort to all sorts of shifts and tricks to evade the viewer's eye. The master complains of the injustice of the inspection, when it is his own fault for employing inferior workmen and screwing them down in price. .5.

Lovell's account which stressed the flawlessness of the Government armoury compared to the workmanship of the Birmingham district was accepted as a clear indication of the "superiority of the Enfield manufactory" by the Master General, who was no doubt looking for ways to alleviate the political pressures placed upon "Ordnance" by the continuing lobby of Parliament by the private gun trade. The April Minute of the Master General when referring to Lovell's definition of Enfield, suggests that this "would be of use to the clerk of the Ordnance in answering any attack in the House of Commons". .6.

There can be little doubt that Lovell harboured strong and lasting opinions regarding the inadequacies of the private gun trade, singling out Birmingham manufacturers as a particular example. It is also abundantly clear that he favoured the notion of having Government owned and run establishments for the manufacture of military supplies. In 1830 he had taken the trouble to write a lengthy critique on blank sheets opposite the main text of an anonymously published pamphlet on the "Observations on the Manufacture of Fire-Arms for Military Purposes" where he expressed the following vehement views:-

> It is the <u>first</u> Duty of every Department entrusted with the details, to see that our Fleets and Armies be equipped at every point in the <u>most perfect manner</u>.-
> In all the essential parts this has been tried by competition in Private hands, and failed:-1st: Our ships of war, when built by Contract were notoriously unsound!-The Navy Board

were obliged to increase the number of Publick Dock Yards.- 2nd: Our Gunpowder made by Private hands would not reach our enemies!-The ordnance Department established their own Powder Mills.-3rd: The Carriages of our field and Battering Guns when made by Private Carpenters were disgraceful!-The Royal Carriage Department was instituted.-4th: The arms of our Soldiers, made by Birmingham Contractors were as proverbially "bad as a Brummagen Halfpenny" and even to these the supply was deficient!-The Royal manufactory of arms was in consequence established.- These several Institutions have arisen and increased out of pure necessity:-The Government has positively been driven into the measures, and what are the results?-
Our Ships, our Powder, our Artillery, our Arms, are acknowledged even by our enemies to be superior to all the world.-

That System is good which works well!- .7.

While it is probably fair to say that some of these comments contain elements of emotion, nevertheless it is a particularly damming judgement not only of the private gun trade, but private industry generally. It is obvious from Lovell's exposition that he firmly believed that only properly administered government establishments were capable of turning out work of a satisfactory standard. Comparing these earlier opinions with those he espoused in 1852, suggest his views had not changed that much with regard to the private gun trade's quality of workmanship.

However, in contrast, if one examines Lovell's evidence given before the 1849 Select Committee on Army and Ordnance Expenditure, a completely different picture emerges. Lovell was questioned by Sir James Graham on matters relating to the possible advantages of "Ordnance" having in-house production of small arms. Responding to the point put by Sir James "You do not concur in the opinion that it would be desirable to manufacture as the exclusive mode of supply"? Lovell replied, "Certainly not; we should then have no check upon our own men". Confirming the response Sir James continued; "You would prefer contract as the rule, with Enfield as the check"? To this Lovell replied; "Yes, Enfield is useful as a check". Making absolutely sure what Lovell had in his mind Sir James pressed home the point; "You would keep the establishment at Enfield as low as possible, keeping in view the necessity of it as a check"? Lovell replied; "Yes". .8.

On the face of the 1849 evidence, it would appear that Lovell had completely reversed the strong views he had expressed in 1830 and accepted the role of Enfield as a minimum manufacturing establishment which would act as "check" upon the private gun trade. It is interesting to note that he volunteered the opinion that the private gun trade would act as a "check" upon his "own men", a complete contradiction of his earlier and later views when he had boasted that they were "first class" in their trade.

The example of Lovell's apparent change of direction from his erstwhile opinions can be seen in his report of April 1852 (mentioned above), illustrating a side of Lovell bordering on the devious. This aspect of Lovell's character has never before been discussed. The report shows that he held clear views regarding the superiority of the workmen employed at Enfield over those doing comparable jobs in the private sector. While these later opinions appear less vigorous than those expressed in 1830, it does, however suggest, that he had not altered his original strongly held beliefs and that his evidence to the 1849 Select Committee formed part of a "smoke-screen" to cover a secret plan he was nurturing.

At first glance, the seeming contradiction in Lovell's views appears puzzling. However, if we try to see the situation which confronted Lovell through his eyes, from the perspective of his burning ambition to equip the British soldier with the best possible weapons, while at the same time being constrained by "Ordnance" regulations and the private sector's lobby of Parliament, we may imagine the various schemes which could have gone through his mind. At the time there were many personal attacks by members of the gun trade upon Lovell's character which were probably causing his superiors some discomfort, therefore he may have considered discretion to be the better part of valour, deciding not to reveal his true opinions in public. Perhaps there were personal pressures for his less forthright stance. At the time, an enquiry was in progress into the behaviour of Lovell's son Francis, the Assistant Inspector of Small Arms, who had compensated the French gun stock contractor Pierlot & Siminos for losses sustained in a Government contract for gun stocks. The inquiry continued until July 1852, when Lovell junior was sacked. It is clear from the ensuing correspondence with the Master General that Lovell senior was deeply upset by the incident. Returning from leave he wrote to the Board of Ordnance on the 19th July, asking them to reconsider their judgement. In his letter Lovell stated he "deeply deplores" the fact his son should have exposed himself to want of discretion, although in support he suggested the inquiry had found no "moral turpitude" in his son's actions. Lovell believed the incident had brought disgrace upon his house. His letter expressed the view that the "sentence" would weigh heavily on "a large family of brothers and sisters". The Board ignored Lovell's pleas, and did not reverse its judgement. .9.

A brave try to change the procurement system?

The evidence placed before the 1854 Select Committee on Small Arms, included the debate carried on in correspondence since the early 1840s between George Lovell, the Master General, and Board of Ordnance over Lovell's plan to break what the Board perceived as an endless cycle of poor quality and late delivery by the private contractors. Lovell had pointed out that the gun trade in London and Birmingham had joined in combination against "Ordnance". Therefore he concluded that it was impossible for the system of placing contracts to work as the competitive element had effectively been removed. Furthermore, he explained that the gun trade workers had in turn joined Trade Unions and were acting in combination against their masters by striking for better wages. In spite of this, and his considerable reservations of the private gun contractor's ability to produce sufficient quantities of good quality weapons, Lovell advanced what would seem to be a very sensible and practical approach to ease the situation when he suggested:-

> ... before I can propose any further orders being issued, it appears to me to be absolutely necessary for the security of the public interests, that a better understanding should be come to with gun contractors, and that the prices of setting up arms should be thoroughly investigated, and regulated upon a more fair and reasonable base than they have hitherto been. .10.

Considering Lovell's strongly held views of the private sector, this was a revolutionary proposal. Lovell went even further by suggesting that he thought the arms supply and quality situation could be remedied if he was allowed to call a meeting consisting of representatives from the London and Birmingham gun trades to which he would attend with the Storekeeper from Enfield, R W Gunner. He also suggested that the Board of Ordnance should nominate a suitable person to be present. As Lovell explained, his reasons for calling the meeting was so:-

> That every process in detail should be gone carefully through, item by item, and that the prices that are to be paid to the workmen fixed and settled: taking the scale of prices paid in the Royal manufactory as a guide, but subject to such modifications as the differing circumstances of the private trade may point out as necessary; and when this has been done, that the per-centage shall be determined upon, which the contractor shall receive for his outlay of capital, his risk, losses, time and trouble. .11.

Lovell went on to say "I would further advise, that the workmen's prices, when so fixed, for Ordnance work, should be printed and distributed, and that no contractor should be allowed to give more or less". .12. This was a brave and ambitious proposal and clearly shows that Lovell had a good understanding of the working of the private sector. It is doubtful if Lovell would have made such a proposal on the spur of the moment, it is more likely that he had taken time to carefully consider and formulate his ideas during his period at Enfield. Furthermore, it demonstrates that although Lovell was harbouring strong personal beliefs about how and where weapons should be made, he could astutely weigh up the political situation, probably judging that in the relatively peaceful inter-war period there was little opportunity for "Ordnance" to take outright control of small arms manufacture. Such an action would also have been difficult to achieve, given the frequent questions, raised within the House of Commons by vocal members who were supporters of the gun trade, regarding the military public spending estimates. .13. Lovell's way forward was to recommend to the Board of Ordnance a radical overhaul of the contract system, which if implemented would have helped to address the serious haemorrhaging of skilled workers from the industry as labour was cast off in peacetime.

Quite soon after his promotion to Inspector of Small Arms in 1840, Lovell placed his plan before the Board of Ordnance. It is clear from the correspondence that Lovell's thoughts were focused on the survival of the British gun trade as a whole, as he had prepared his case with care by taking prior soundings in the private sector. Lovell explained, "I have mentioned this proposal to some of the leading contractors at Birmingham and in London, who are quite ready and willing to enter into such an agreement". In view of this bold initiative, it may seem somewhat ironic that Lovell was to come under an increasing number of personal attacks and criticisms by the gun trade at large, particularly for the strictness of inspection imposed by his viewers, when it would appear, at least on the surface, that he was desperately trying to improve the overall conditions within the small arms industry. Perhaps the trade was becoming wary of Lovell, suspecting that he had an ulterior motive. On the one hand he was apparently trying to improve the conditions of the contractors and their workers, while at the same time he was tightening the quality screw.

Although the logic of his proposals seems to have been recognised, Lovell received the following reply, "... the Master General and Board cannot of themselves interfere in any proceeding affecting the arrangements of the contractors with their workmen". .14. The Board's response does not appear to have put Lovell off striving to achieve his objective, as he single-mindedly and courageously persevered with his ideas, writing some eight years later:-

> I have since the year 1842, been enabled to bring about an understanding between the masters and workmen, and to establish a "List of Prices of Labour," by which every master has agreed to be governed; which the workmen themselves find to operate beneficially, and which has had the effect of doing away with "strikes" for wages ever since. .15.

However, Lovell does point out that while he considered the prices paid for labour in the gun trade generally fair and reasonable, he did feel that the profits of the masters should be brought into competition. As an example, he highlighted the trade's setting-up costs for the new percussion musket which he was able to measure quite accurately against similar work carried out at Enfield. From this he concluded that the masters because of the method of payment, were regularly deriving an advance of 7 shillings and 5 pence (24.5%) monthly against each gun. This sum, Lovell suggested, can be turned over twelve times a year "without any risk of the bankruptcies or delays the mere private commerce brings with it". .16. He therefore reasoned that the 24.5% was the sum, more than any other, which the gun trade would be prepared to negotiate down in open competition, providing the number of contracts put out were strictly regulated by the Board and extended over periods of not less than three years. .17.

It can be seen, that Lovell has identified a major problem with the "Ordnance" contract system, that of its short term nature. This observation has highlighted a further important point. Should "Ordnance" have offered the private sector long term or guaranteed follow-on contracts, then initial tooling-up and other associated costs could have been amortised across a longer production run, resulting in customer benefit from a lower product price. This perhaps illustrates that members of the Board did not fully understand the manufacturing requirements. These issues will be addressed in Chapter Eight.

In achieving his plan, Lovell wrote "I have sedulously avoided lowering the quality of the musket either in workmanship or material; for in that I am convinced there would be no true economy". He concluded his letter of December 1848 in confident mood by drawing the Board's attention to the following current supply position (the desiccating process will be discussed separately in the next chapter):-

> ...by the perfect success of the desiccating process for seasoning stocks, which is now in full operation at Enfield, and by the powerful assistance of the machinery for jointing and percussioning, which I have introduced of late years, and looking to the store on hand, I can be certain of providing in regular succession a sufficient supply of stocks, locks, bayonets, and all other materials, to whatever extent and for whatever period may be determined upon". .18.

It is clear from Lovell's proposals regarding the introduction of long term contracts that he was trying to introduce a strong element of stability into the gun making industry. Over the years the gun trade were subjected to great pressures to supply large quantities of arms in time of war but during peacetime orders were not forthcoming. Had Lovell's policies concerning contracts and payments been fully implemented, and as yet there is no evidence to suggest that they were, not even partially, it would have gone a long way towards solving the problems of gun makers poaching skilled workers from other gunsmiths in times of boom, and the workers themselves plying their trade between several masters at once. All these movements of people were known to affect seriously the quality of the product, which in turn led to delays as "Ordnance" rejected deliveries of unsatisfactory weapons and parts.

<u>A change of tactics by Lovell?</u>

Studying the fully documented evidence of the 1854 Government Select Committee on Small Arms can be both fruitful and rewarding, in teasing out subtle clues concerning what would appear to be Lovell's hidden agenda.

One of the most revealing pieces of evidence to come before the Committee was from the Birmingham gun maker, Isaac Brentnall Sheath, who had contracted to set up a quantity of arms for "Ordnance" in 1851. The contract had not been completed on time. When questioned about the delay, Sheath gave two main reasons. These were "...not having materials", and "...the pattern was not decided upon by the Board of Ordnance to enable us to proceed with it". He was then asked, "have you not a proper pattern given to you at first"? Sheath replied, "no we never have patterns allowed us". This is quite an extraordinary revelation, as without a pattern for reference, it would have been almost impossible for the setting up contractor to ensure that the work being carried out was in accordance with the required "Ordnance" standard. From the testimony it is learned that the closest the contractor is able to get to the pattern is at the "Ordnance" viewing rooms. Sheath elucidates, "the pattern is placed in the viewer's hands, and we send a workman down to the viewer to have our jigs made in his presence, and then he explains the different points that he wants attended to". .19.

The understanding of the consequences of this arrangement and its impact upon quality and standardisation is a crucial factor in explaining the differences which existed between mid century American machine made weapons and their British labour intensive counterparts. To have grasped the implications and significance of how the private sector had to cope with "Ordnance" small arms contracts under such unreasonable conditions of working, may have allowed some contemporary writers to have been a little more generous towards the independent gun trade's manufacturing capabilities.

It is worth reminding ourselves once more of the information contained in the letter dated 12th September 1854, from Hollis & Sheath to Joseph Wood, Secretary Ordnance Office, (discussed in the last chapter) and comparing this evidence with the revelations by Sheath to the Select Committee earlier that March regarding the 1851 setting up contract. This would appear to reinforce the notion that "Ordnance" had learned little from their earlier experiences of poor quality and late deliveries. In the letter, the contractor suggests that "...we believe we can complete the 20,000 musket pattern 1853 in March next, providing we have the materials (less sights) issued to us at the rate of 200 each per week from this date." What is more revealing comes later in the letter when the contractor suggests that he will be able "...to keep pace with the setting up..." "...as soon as the proper tools are prepared for viewing the sites...". .20. It is clear that the reference to "tools ... for viewing the sites

...", refers to measuring gauges. On the face of this information it does seem incredible that after three years "Ordnance" were still not prepared, or were slow, to let contractors have patterns or gauges to check that their work conformed with the standards they themselves had set. It will be recalled from the Hollis & Sheath letter that it was not absolutely clear who was responsible for making the gauges, the contractor or "Ordnance". Neither is it clear, when the later pattern 1853 contract was issued, that "Ordnance" would be supplying the contractors with master patterns on time.

From the recommendations contained within the report of the 1854 Select Committee on Small Arms, "... that in future the contract should be understood to commence from the time of the delivery of the pattern ...", one might conclude that old ways were slow to change. .21. Either way, it would seem "Ordnance" were at fault. If they had not supplied the pattern, then, without this essential standard to work from, it would have been impossible for the contractor to construct accurate gauges. Therefore, it is difficult to see how essential work on the weapon could have commenced. On the other hand, if it was the responsibility of "Ordnance" to supply the gauges, then we know from Hollis & Sheath's letter that they had not done so. What is perhaps more surprising, particularly when considering the Master General and George Lovell's previous views of the private sector (with "the man who will work for the lowest rate"), that it had still not been planned to ensure dubious quality was filtered out at source prior to the weapon or component being submitted to the "Ordnance" viewers. This could have easily been achieved by supplying contractors with duplicate sets of gauges and patterns. After all, it was as much in the financial interests of "Ordnance" as of the contractors to get the article right first time. Delays and quality problems emanating from the inability of contractors to accurately check their work would no doubt have posed a grave risk to Britain's national security when demand for weapons increased in time of war.

George Lovell accomplished many positive things in his long career. However, the notion that contractors should be deliberately denied duplicate sets of gauges and patterns seems to go against all the very bench-marks he was trying to set in his quest for quality and standardisation. By effectively forcing the various contractors to make their own jigs (and perhaps gauges) from a pattern held by the viewer, it can surely not have escaped the attention of "Ordnance" that it would have been almost impossible to achieve uniformity of manufacture. Gauge making was carried out by the highest skilled craftsmen, some of these precision tools taking many months to make and perfect. If Lovell was genuine in his belief regarding the low level of competence of the private sector craftsmen, it would seem folly in the extreme to have trusted contractors to manufacture their own gauges and expect precision. Furthermore, if "Ordnance" were deliberately forcing the individual contractors to manufacture their own duplicate sets of gauges, then it must have been realised that the outcome would have resulted in considerable delays in the military weapon supply chain. Moreover, it would have been difficult if not impossible for each individual contractor to meet a consistent standard of component tolerance, as it is highly unlikely that all the gauges could have been made to a precise specification in the different manufacturing establishments.

In Britain at the middle of the 19th century, concepts of manufacturing from a controlled single standard were known and understood. Much of the pioneering work had been done by eminent engineers like Henry Maudslay and Joseph Whitworth, who had both set national bench-marks for accurate measurement. Had "Ordnance" adopted a policy to supply patterns and gauges to the contractors they could have ensured that these tools complied with a single set of standards. As viewer's gauges and patterns were already made by "Ordnance", the logical plan would have been to extend this work and make duplicate sets for the contractors. Although this action may have seemed costly in the short term, in the longer term the outlay could have been recouped by cutting the reject rate, saving material, reducing losses incurred through delays and ensuring the army and navy were equipped on time.

To ensure the system operated fairly, independent officers within "Ordnance" could have held master sets of patterns and gauges to act as arbitrators should a dispute over standards of acceptability arise. These are not simply the retrospective views of a 20th century writer, as Sheath had put forward similar ideas in his evidence to the Select Committee. If gauges and patterns had been made for the private gun trade at Enfield, the work would have corresponded with the role already adopted by the factory which functioned largely as a unit for specialist and experimental work. More than any other British establishment, Enfield was ideally suited to the task, particularly as one is mindful of Lovell when he said of the place "no workman is admitted unless he be of the first class in his trade". Had "Ordnance" taken responsibility for making and issuing all gauges and patterns, then they would have been in a stronger position to accurately monitor the work of the private sector with greater authority. Contractors would have had little room to complain of misunderstandings over manufacturing dimensions and there could be no excuses for delays to finished product due to lack of measuring equipment. Therefore, with the knowledge and means of accurate systems of measurement open to Lovell and his colleagues, one can only speculate why a universal scheme was not adopted for "Ordnance" contracts.

<u>A hidden agenda?</u>

While "Ordnance" were continually complaining of high reject rates and late delivery, it is difficult to comprehend why they had apparently not considered issuing patterns and gauges to at least the major setting up contractors. The necessity for a closer watch on accuracy and quality would have seemed an obvious precaution when the system of open tendering was first introduced in circa 1850. With the emphasis firmly on lower prices, this could have attracted inexperienced companies to tender for business in the hope of establishing themselves as "Ordnance" contractors.

As the system of open tendering had been introduced when Lovell was Inspector of Small Arms, being brought about by his recommendations to the Board of Ordnance, one would have expected that a man of his intellect, desperately striving to achieve standardisation of parts and weapons, would at least have put the idea to his superiors of issuing patterns and gauges to the contractors. Research to date has not been able to uncover any evidence which might suggest that Lovell had discussed or recommended these fundamental principles to the Master General or to members of the Board. Could it be that Lovell was cleverly developing a hidden agenda? If the private gun trade could be subtly denied the wherewithal to manufacture weapons to a satisfactory standard, then this would leave the way clear for "Ordnance" to take control of the production of military small arms, allowing Lovell to realize the ambition he had proffered in 1830. It might therefore be construed from Sheath's experience that Lovell, by <u>deliberately</u> denying the contractors patterns and gauges for the 1851 contract (although this was never outwardly obvious from the evidence taken before the Select Committee) was trying to ensure that the private gun trade would fail in its attempt to supply "Ordnance" on time with good quality arms.

If this was his hidden agenda, it would have allowed Lovell the opportunity to persuade the Board that the plans he had advocated earlier for setting prices and wages within the private sector, which the Master General had rejected, were worth reviewing once more. Had the Board then decided to accept an interventionist role, adopting a policy similar to Lovell's earlier proposals for the contractors, this compromise would have gone some way to meeting his 1830 aspirations, when he had advocated "Ordnance" taking total responsibility for the production of all weapons supplied to the military.

Parliament on the other hand, which had been under pressure from the private gun trade not to expand the "Ordnance" capability of military small arms manufacture, would no doubt have welcomed the financial benefits to be gained from such an outcome. This concession, if implemented, would also have met Lovell's opposite view, expressed in 1849, when he agreed that he "would keep the establishment at Enfield as low as possible...". .22. In other words, if Lovell was unable to realise his main ambition, that of "Ordnance" taking over full manufacturing control of military weapons from the private sector, then the lesser option would have provided a face saver. Of course these suggestions are no more than speculation, but Lovell was a man of considerable intellect who wanted his ideas adopted, and as De Witt Bailey has pointed out, he wished "...to ensure that Britain's soldiers could defend their Empire with an unfailing supply of the best possible weapons which technology and experience could produce". .23. It is therefore conceivable that the suggestion of Lovell harbouring long term plans for "Ordnance" to take control of the manufacture of military small arms, was his way of trying to ensure the British soldier got the best.

<u>What was Lovell's motive?</u>

While it is not intended to devalue Lovell's magnificent contribution to the British arms industry, research has shown that he was generally over ambitious in his application with regard to the strictness of view. Of course it might be argued that by applying such rigid standards of inspection, it was

Lovell's plan to force the private gun trade into employing more machinery. This was surely not his intention, as Lovell was fully aware of the gun trade's reasons for not investing in higher quantities of equipment, their reluctance being primarily due to the short and intermittent nature of the contract system, which gave little confidence or incentive to commit capital to machine intensive programmes when the future was so unsure. It will be recalled that Lovell, as early as 1842, had recommended to the Board methods of regulating wages and prices within the private sector. He had also suggested that it would be advisable to offer the gun trade a minimum contract period of three years. Therefore, it is more likely that Lovell, frustrated by the reluctance of "Ordnance" to intervene in the private sector over wage and price structures and unable to reduce the sector's influence upon Parliament, was preparing his own agenda to force the Board's hand to a greater manufacturing commitment.

From the evidence of the contractors given before the Select Committee on Small Arms in 1854, it is known that they had either not been issued with patterns, or at best had to wait their turn. This could cause considerable delays to individual firms completing their part of the contract. James Gunner (son of R W Gunner) had reported to the Committee that one pattern was supplied "as a guide" for all the manufacturers, which if correct was a most unsatisfactory way of working. .24. There is confirmation of this point through the evidence of Richard Aston who worked with his brother as a "General Gun Furniture Maker" (odd metal parts of the gun stock and elsewhere). Aston gave the reason for being late with deliveries of the 1851 bayonet because "... we were seven weeks before we got the pattern". When asked if he had ever applied for a duplicate, he replied "Many times; and Mr Lovell said that I should be the first to find fault with it". Asked what he had meant by this, Aston alleged that Lovell had said "they could not make six or seven near enough to view to". .25.

This remark would appear extraordinary in the light of Lovell's boast that Enfield employed only skilled artisans. If this was the real position, it would seem hardly fair to have expected high standards from the private sector considering Lovell's low opinion of them. And of course, Lovell was well aware that he had been more than economical with the issuing of patterns and gauges. As Enfield already produced a number of duplicate gauges of high accuracy for the "Ordnance" viewers to check the contractors work, the excuse offered through Aston would not seem plausible. More likely Lovell was offering Aston the least line of resistance, perhaps not wishing to reveal his innermost thoughts. If Lovell had issued duplicate patterns and gauges, then as suggested above, he would have lost the initiative to blame the contractors for failing to honour their agreements with "Ordnance".

It is known from correspondence that George Lovell was signing letters as Inspector of Small Arms in 1853. This would confirm he still had overall responsibility for manufacture and inspection. From this, one can only conclude the responsibility for issuing the precise means of measurement to the contractors was entirely his. If he was somehow denying the contractors the ability to measure work accurately to assume manufacturing control, then as an employee of "Ordnance" he was taking a dangerous strategic gamble. Clearly it would have been physically impractical for the different contractors in London and Birmingham to check the accuracy of their work from a solitary pattern held by the Government viewer before submission to "Ordnance". Such an arrangement would seem completely out of character with Lovell's enthusiastic drive towards improved weapon quality and standardisation. However, as suggested above, it is possible that Lovell's judgement may have been influenced by the incident concerning the Master General and the Board's treatment of his son Francis over the compensation of the French gun stock contractor. The influence of the gun stock episode (debated separately in the next chapter) upon Lovell's state of mind is probably no more than one would expect from a man whose health was failing, as is evidenced by the shaky and deteriorating hand writing in correspondence towards the end of his career. Arms expert and historian Howard Blackmore has implied that the incident led eventually to Lovell's demise and has described it thus. "Lovell himself was admonished and ordered to move to Birmingham where most of the new rifled muskets were in the hands of the contractors. He died in 1854, his achievements forgotten and largely blamed for the failure of the system". .26.

However, the argument suggesting faulty judgement due to Lovell's poor state of mind can only be upheld if his later life is taken in isolation, clearly an unsustainable proposition. As Lovell had been appointed Inspector of Small Arms in 1840, he would have had both the authority and the opportunity to have developed and put in place a strategy for issuing duplicate sets of patterns and gauges to contractors had he so wished. Therefore, to argue that Lovell's downfall had somehow been caused by failing faculties later in life after the gun stock episode with his son can confidently be dismissed.

The most likely reason for Lovell's final isolation, as suggested by the overwhelming evidence, was his single minded devotion to the quest for small arms perfection by hidden agenda or otherwise. This outwardly manifested itself in his uncompromising adherence to the strictness of viewing standards, placing the independent gun makers in an impossible position. Support for this opinion can be seen in the evidence of Joseph Brazier when he explained that viewing had become less strict when Richard Webb Gunner took over the responsibilities of Inspector of Small Arms from Lovell.

The evidence suggests that Lovell never gave up his quest for perfection. This therefore makes it difficult to fully understand why the private sector had not been issued with the necessary measuring tools to do the job. Under the circumstances, one would have expected the private gun trade to have been given the opportunity on at least one major contract to accurately measure their work, even as an experiment. Perhaps this denial implies that Lovell really did have a hidden agenda.

<u>An impossible task for the private sector</u>

Because of the strictness of view, the private gun trade was unable to cope with the more exacting levels of inspection imposed when the new system of open tendering was introduced in circa 1850. Without standardised gauges or patterns, the private gun trade found it almost impossible to cope with the military contracts. Having only manual methods of manufacture to rely on the gun trade was trapped, unable to meet economically the new exacting standards imposed by the viewers under Lovell's authority. The effect upon the industry was chaotic, with contractors failing to meet their delivery dates and, as a consequence, suffering financial penalties and material loss. Once Lovell had set the standards for tighter inspection he could not have easily gone back, even had he wanted to do so. Apart from a loss of face had he reverted to former standards it would have created confusion amongst the viewers. If the harsh measures he had imposed were designed to force the private sector into failing, then Lovell had not fully succeeded. Neither had he been able to convince Government that an "Ordnance" committed to full-scale military small arms manufacture was the only way forward.

However, if Lovell was not operating a hidden agenda and was genuinely trying to organise the private gun trade into a first class British arms industry, then surely he could not have failed to recognize the most practical way of achieving his goal was to invite co-operation by developing a co-ordinated strategy for the industry, not by alienating the participants by denying them the wherewithal to check their work. After all, he had laid the foundations earlier by ignoring the Board's instruction when he unilaterally decided to discuss an improved price structure with both masters and men. Nevertheless, by his adherence to strict standards of tolerance and finish and by withholding gauges and patterns, he had alienated a large section of the would-be participants. Therefore it was hardly likely that he would personally realise his passionate ambition.

Had Lovell seen the report of the Select Committee published in May 1854 before his death in April that year, he may well have realised that there were other ways of improving the supply of good quality military arms through a more liberal policy of collaboration with the private sector. With his first rate knowledge of the gun trade, Lovell must have been well aware of the East India Company's methods of procuring arms from the private sector. While it is recognised that the East India Company's methods were not perfect, they did have an infinitely better customer supplier relationship, and were therefore more likely to resolve difficulties mutually with their contractors than "Ordnance". Had Lovell approached his quest for perfection on a similar basis and secured the support of the Board of Ordnance, we may have seen a different outcome for the British small arms industry. Of course one can be wise with the benefit of hindsight.

De Witt Bailey, in summing up Lovell's contribution to the British arms industry, states, "Lovell was the most effective and successful standard-bearer in the struggle between the two opposing factions regarding the hotly contested question as to whether the Government or the private sector should control the manufacture of Britain's military small arms. Throughout his career Lovell was passionately dedicated to the concept that the central Government should control the manufacture of military small arms...". .27. While Lovell's passion to see an efficient well run military small arms industry can not be denied, from the evidence so far uncovered he can not really be classified as the "standard-bearer" in the contest for Government control of the military small arms trade, as all his public statements do not support this view.

Lovell's real ambition posthumously achieved

Sadly, it was not until 1857, less than three years after Lovell's death that his innermost ambitions were to be fully realised. Provoked by the war in the Crimea, the Government controlled factory at Enfield Lock started production with the newly acquired machine tools from America. Now it was possible for Enfield to achieve levels of standardisation of which Lovell could have only dreamed.

It had been the continuing pressure upon Parliament from the private gun trade which had helped tie "Ordnance" hands for so long. Support for the private sector by politicians had remained firm. In a letter to the editor of the Aris's Gazette in March 1852, the Birmingham M.P. William Scholfield, added a conciliatory note to a dispute between the gun manufacturers and their workmen when he took the opportunity to warn of the possible dangers facing the trade:-

> Already it is understood that the Government has largely extended the operations of Enfield, and, no longer confining itself to repairs and experiments, has undertaken many processes of manufacture; and it is seriously to be feared that the Ordnance Office will not be slow to avail itself of

any excuse for still further steps in this direction. .28. Before the 1854 Select Committee on Small Arms had been appointed to consider the cheapest and most efficient way of providing weapons for her Majesty's service, John Dent Goodman was to observe:-

> Before this resolution was carried out the subject was warmly debated in the House of Commons, Mr. Newdegate, Mr. Muntz, Mr. Geach, Lord Seymour, and other members strongly insisted upon the impolicy of Government entering into competition as manufacturers with the private trade of the country .... .29.

Even as late as 1868, eleven years after Enfield had commenced full-scale production, the continuing influence of the private sector could still be recognised. John Bright M.P. addressed a deputation of Birmingham gun-makers, when it was stated:-

> The object which these manufacturers had before them was to criticise the action of the Government in establishing manufactories at Enfield and elsewhere, and generally to condemn the policy of Government in undertaking such commercial or industrial operations as can be carried out adequately and safely by private enterprise. .30.

Had Lovell been allowed in the early 1840s to negotiate improved contracts with the gun trade, there may have been a different outcome as to how the military would be supplied in the future. Although the Government eventually had to commit large sums of money to upgrade Enfield, it is probably fair to speculate that they would have preferred to have obtained their arms from the private sector, thereby saving vast amounts of public funds. No doubt politicians appreciated that once small arms manufacture had been taken on by Government, there would be a continuing requirement for a long term financial commitment. Under the circumstances in which they found themselves, their hands forced by war, there was little choice but to take "in-house" control.

However, the Lovell period had helped shape Enfield, providing the factory with the necessary discipline which would be required in its future role as a major small arms producer, bringing it for the first time into unfettered competition with the private gun trade. Had George Lovell been alive to witness the scale of the new factory, he would no doubt have been justly proud. While the strictness of inspection he had imposed was probably too ambitious for the day, he had nevertheless broadened the debate on precision and standards.

NOTES.

.1. Public Record Office, Kew. WO44/304

.2. Bailey, De Witt, George Lovell and the Growth of the RSAF Enfield, Paper presented at MA Day School, Middlesex University, 4th July 1992, pp.5-24, also see for more information on George Lovell, House of Lords Record Office, The Committees Army and Ordnance Expenditure Session, 1st Feb - 1st Aug, 1949. Vol.9, pp.301-302. For further reading on Lovell, see: Blackmore, Howard L, British Soldiers Firearms (1650-1850), (London 1961) pp.205-234. For the sequence of weapons developed at Enfield, see: Reynolds, E.G.B., Early Enfield Arms The Muzzle Loaders, Small Arms Profile No.14, pp.24-28

The main product assembled at the Royal Armoury Mills, at Enfield Lock, as it was known in the early years, was the Brown Bess smooth-bore musket (Fig.1). This weapon had been the personal arm of the British soldier until the arrival of the flint lock Baker rifle (Fig.2) with its barrel containing seven rifled grooves. The technique of rifling had been developed to improve accuracy of fire. This was achieved by spinning the projectile, giving it greater stability in flight, making the weapon's performance superior to that of the earlier smooth-bore muskets. Unfortunately the introduction of rifling to the inside of the previously smooth barrel of the muzzle-loader, made loading more difficult because of the grooves presenting resistance to the ball. In an effort to overcome the problem, for a time a small mallet was issued with each weapon to assist the ramming of the leaden ball down the barrel. This crude method of loading often resulted in distorting and jamming the ball.

The Baker rifle was to be the last of the British military flint-locks. In 1831 a number of muskets were converted to the percussion system and in trials proved to be more accurate and reliable than their predecessors, giving less recoil and a greater rate of fire. Conversion was effected by replacing the hammer, spring and pan, the cock being substituted for a percussion hammer. A small hollow pillar was fitted into the barrel to hold the detonating cap. After many experiments with both British and foreign designs in the late 1830s and early 1840s, George Lovell, prior to taking up his new appointment, was responsible for the introduction of the two grooved Brunswick rifle (Fig.3). The rifle fired a spherical lead ball with a raised belt around its middle, designed to fit the grooves in the barrel. This arm came next in the evolution of Enfield's weapon development. To improve the introduction of the ball into the barrel, a notch was cut across the muzzle. This modification assisted the belted area into the grooves. After trials at Woolwich the weapon was finally approved and a quantity issued to the Army. Under the guidance of George Lovell the rifle was later converted to side lock action in 1841.

Although certain advantages were claimed for the Brunswick, it was still inclined to suffer from loading problems. It does seem curious that after being in service with the British Army for some fifteen years, a Select Committee on Small Arms was to make the following severe criticisms:- "The Brunswick rifle has shown itself to be much inferior in point of range to every other arm hitherto noticed. The loading of this rifle is so difficult that it is a wonder how the rifle regiments have continued to use it so long, the force required to ram down the ball being so great as to render any man's hand unsteady for accurate shooting".

.3. Op.cit., Bailey, p.5

.4. Op.cit., Reynolds, p.26

.5. House of Lords Record Office, London.
Report from the Inspector of Small Arms, relating to the differences between Birmingham and Enfield,
George Lovell, 3rd April 1852. Included under, Appendix to Report from the Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, pp.450-451 (488)-(489)

.6. Ibid., Minute of Master General, p.451 (489)

.7. The British Library, London.
"Observations on the Manufacture of Fire-Arms for Military Purposes", British Library Catalogue No. 08820 b25, Longman & Co. and James Drake, (London 1829), p.158. Also see, Rosenberg, Nathan, The American System of Manufacturers, Edinburgh University Press, (Edinburgh, 1969) p.38

.8. House of Lords Record Office, London.
Reports from the Committees Army and Ordnance Expenditure, Session: 1st Feb - 1st Aug, 1849. Vol. 1X.
Examination of G Lovell, Esq. 4th May 1849, p.308

.9. Public Record Office, Kew.
Correspondence and report concerning inquiry into the the Assistant Inspector of Small Arms, Francis G Lovell.
WO 44/701. Also see Chapter Four in this thesis for fuller explanation.

.10. House of Lords Record Office, London.
Letter from the Inspector of Small Arms, relative to the Progress made in the Preparation of Percussion Arms,
George Lovell, 10th September 1840. Included under, Appendix to Report from the Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.452 (490)

.11. Ibid., p.452 (490)

.12. Ibid., p.452 (490)

.13. Public Addresses by John Bright M.P., Edited by James E Thorald Rogers, Macmillian & Co. (London 1879) pp.143-144

.14. House of Lords Record Office, London. Memorandum from Secretary, War Office, J. Wood, 23rd September 1840. Included under, Appendix to Report from the Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.453 (491)

.15. House of Lords Record Office, London. Letter from the Inspector of Small Arms, respecting the Disadvantages of the System pursued for obtaining Arms, George Lovell, 16th December 1848. Included under, Appendix to Report from the Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.455 (493)

.16. Ibid., p.455 (493)

.17. Ibid., p.455 (493)

.18. Ibid., p.456 (494)

.19. House of Lords Record Office, London. Examination of Mr Isacc Brentnall Sheath, 29th March 1854, Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.323 (361)

.20. Public Record Office, Kew. Letter to J Wood, Office of Ordnance, from Hollis & Sheath, 12/9/1854. Reference WO 44/701

.21. Op.cit., Report from the Select Committee on Small Arms, 1st March 1854, p.10

.22. House of Lords Record Office, London. Reports from the Committees Army and Ordnance Expenditure, Session: 1st Feb - 1st Aug, 1849. Vol. 1X. Examination of G Lovell, Esq. 4th May 1849, p.309

.23. Op.cit., Bailey, p.11

.24. Op.cit., Report from the Select Committee on Small Arms, 1st March 1854, evidence of J Gunner p.286

.25. Op.cit., Report from the Select Committee on Small Arms, 28th March 1854, evidence of R Aston p.297

.26. Op.cit., Blackmore, p.119

.27. Op.cit., Bailey, pp.10-11

.28. House of Lords Record Office, London.
Letter to the Editor of "Aris's Gazette" from William Schofield M.P., 11th March 1852. Included under, Appendix to Report from the Select Committee on Small Arms. Reports Committee's Vol. XV111-1854, p.453 (491)

.29. Goodman, John Dent, Industrial History of Birmingham and the Midland Hardware District, Ed. Timmins, Robert Hardwick (London 1866) p.397

.30. Op.cit., Public Addresses by John Bright M.P., p.139

TRANSATLANTIC DIFFERENCES AND THE INFLUENCE OF THE GUN STOCK UPON "ORDNANCE" MANAGING INNOVATION

In the previous chapters it has been argued that the Government contract system of arms procurement, the withholding of gauges and patterns from the private gun trade and the strict inspection standards employed by "Ordnance" viewers under the watchful eye of George Lovell all contributed to the technological pause in the progress of Britain's military sector of the small arms industry. In other words it was the way "Ordnance", a public sector establishment, did business which had determined the position, structure and development of the military sector of the private gun trade in the first half of the 19th century, effectively keeping it tied to a system of mainly labour intensive manufacture.

However, in America, the government had adopted a different approach to its British counterpart, encouraging and cooperating with entrepreneurs and others in the field of machine tool and interchangeable small arms technology. The economic and political reasons accounting for these differences which have been advanced by leading commentators have been examined in Chapter Four.

While some of the reasons highlighted above have helped to explain why there was a technological pause in light engineering development in Britain, we have not fully explored the question: had the conditions been favourable, were there engineers and entrepreneurs capable of taking the technology forward? As one of the most labour intensive components of the small arm is the manufacture of the gun stock, our attention will be turned towards the diffusion of available technology in Britain with particular reference to this part.

Early expertise in Britain

The protection of the expanding world markets was paramount in sustaining the growing British economy. In a military sense, this was primarily achieved by strengthening naval power. In 1796 the British Government appointed Brigadier General Sir Samuel Bentham to the post of Inspector General of Naval Works. Bentham had started his working life as apprentice to the Master Shipwright at Woolwich Dockyard, clearly a good grounding for the task ahead. Whilst re-organising the Royal Navy dockyards at Portsmouth, Bentham was approached by Marc Isambard Brunel with a plan to manufacture ship's pulley blocks by a sequence of machines. This revolutionary concept was successfully recommended to the Admiralty by Bentham who had Henry Maudslay, the gifted London engineer, build the machines. Maudslay constructed the machines entirely of metal, at the time a considerable technological leap forward. Many earlier examples had been constructed with wooden frames. By 1805 the Portsmouth block-making machinery was operational and by 1808 the output had reached 130,000 pulley blocks per year. What is perhaps more remarkable about Maudslay's machines is that they could be altered to accommodate the production of blocks of different shapes and sizes, accounting for over 200 types. This exemplar clearly demonstrates that full-scale mass production with uniform machine made parts was in operation in Britain at the start of the century. It is believed this represents the earliest documented example of machine tools being used in a sequenced factory operation. .1.

Early evidence of creative thinking in Britain with regard to techniques of mechanisation and mass production can be seen in the work of the 18th century engineer and prolific inventor, Joseph Bramah. John Farley, a writer and engineer who knew Bramah, has recorded for us a description of Bramah's lock making workshops from the position of an 18th century observer. Although written after Maudslay's death in 1831, it clearly demonstrates an early preoccupation with solving the manufacturing problems of making a product with standardised parts :-

> The secret workshops ...contained several curious machines, for forming parts of locks, with a systematic perfection of workmanship which was at the time unknown in similar mechanical arts. The machines had been constructed by the late Mr Maudslay with his own hands, whilst he was Mr Bramah's chief workman...Mr Bramah attributed the success of his locks to the use of these machines, the invention of which had cost him more study than that of the locks. .2.

Bramah had also worked on solving the problems of the labour intensive and costly nature of the manufacture of gun stocks. In 1802, Bramah registered patent No. 2652, "Machinery for Forming Gun Stocks, etc". Arms historian Howard Blackmore appears somewhat dismissive of Bramah's invention, mainly on the grounds that he "did not specify that the machines were for that particular purpose". It could be that Blackmore was sceptical of Bramah's submission, as he had not included a drawing with his patent. .3. However, at the time it was not obligatory to submit a drawing with a patent. In fact it is still not a requirement today. In the early part of the 19th century the cost of patent registration in England, Ireland, Scotland and Wales was £310.17s. This would equate to something in the order of £8,000 at today's prices. The procedure for registration was tiresome, involving eight major stages, several minor ones and countless officials, taking about six weeks if followed diligently. This was just to obtain the patent; the specification came later. It was normal for an inventor to employ an agent to pilot him through these stages and of course this would have increased the costs. Therefore, it would seem unlikely that such an experienced engineer as Bramah, or any other serious inventor for that matter, would have wished to incur such excessive costs purely on a whim without being reasonably confident that their work would reach a successful commercial conclusion. .4. It is also possible that Bramah had taken out his patent in anticipation of receiving an order for this type of machinery. This would not seem an unreasonable assumption to consider, as we have learned from Goodman that of the 7,300 workmen in the Birmingham gun trade, there were approximately 2,000 employed in making gun stocks manually. .5.

The nine pages of Bramah's patent provide a relatively detailed description of how he views his invention playing a somewhat revolutionary role, particularly with regard to improving efficiency and productivity within the British manufacturing industry. Bramah recognizes the strength of building on, enhancing and adapting tried and tested methods rather than starting with completely untried ideas. This approach demonstrates that Bramah was cost conscious, while illustrating the mark of a good and experienced engineer, who appreciated the economic benefits to be gained in time and expense from the techniques of continuous development and updating. The following extract from patent No. 2652 allows the reader an understanding of Bramah's thinking:-

> I do not rest the merits of this my said Invention on any novelty in the general principle of the machinery I employ, because the public benefit I propose will rather depend on new effects produced by new application of principles already known, and machinery already in use for other purposes, in various branches of British manufacture. This machinery, and the new construction together with sundry tools and apendages [sic] never in use before are particularly described and explained hereunder. .6.

Henry Maudslay had gone to work for Bramah in 1789, some years before setting up on his own account. It is known that Bramah had initially employed Maudslay for his skill and expertise to solve problems of repeatable accuracy with the mass market locks he was manufacturing. It is therefore likely that certain ideas were exchanged between the two men as they discussed the technical problems of production. If so, this might give added credibility to Bramah's gun stock manufacturing concepts and perhaps in turn Maudslay had been influenced by this association when he came to build the Portsmouth block-making machines. .7.

From the early evidence and dates of American machine tool inventors like Blanchard, Hall and Whitney, it would appear that by the start of the 19th century British manufacturers and engineers had an established technical and physical lead over their American counterparts in mass production techniques. However, the period to the middle of the century saw relatively little expansion of this new technology in Britain. This was particularly true of the lock and stock making branches of the small arms industry. Apart from a few individual examples, there was no immediate rush by industry at large to apply the techniques developed by Bramah, Brunel and Maudslay in a blanket fashion. It was the American manufacturers and engineers who perfected, developed and exploited the technology of mass production with uniform parts, which was strenuously applied to the manufacture of small arms. Later this method of production became known as "the American system of manufactures". The products the system produced and the techniques employed seemed to create an air of scepticism and disbelief among many craftsmen in Britain.

By the time of the Great Exhibition of 1851, housed within the specially constructed Crystal Palace in London's Hyde Park, there was ample physical evidence to support the achievements of American manufacturers in their determined pursuit of uniformity and interchangeability. Exhibits of Hobb's locks, Colt's repeating pistols and the rifles of Robbins and Lawrence, which had probably been selected by these companies before being sent for display, would nevertheless seem to reflect the transatlantic engineering progress and the devotion to standardisation. .8.

Interestingly, as it will be seen later, there is evidence to suggest that American manufacturers had only just begun to exploit the advantages of interchangeability through the use of newly developed machine tools, particularly with regard to small arms. However, David Hounshell and others have shown that by the second decade of the century, American clock makers, Eli Terry in particular, were mass producing two and a half thousand wooden clocks per year in four styles, by using machinery and only thirty workmen. .9. In spite of this early mass production breakthrough, Hounshell has readily accepted that the component parts of these clocks were not interchangeable. He concludes, "Terry's objective was not to revolutionize industrial techniques [but]...simply to produce clocks in quantity cheaply". .10. It will therefore be appreciated that engineers had to solve many difficult problems to take early 19th century machine technology from a system of non-interchangeable mass production using wood, to a precision system of interchangeable manufacture using metal by the middle of the century. However, many respected commentators of the period have allowed the notion to grow, perhaps inadvertently, that American manufacturers had embraced interchangeable precision machine intensive production much earlier in the century, using it across a broad range of products, and were therefore less reliant on manual labour.

British reluctance to change

In Britain, for reasons already debated, the transition to interchangeability in weapon production was exceedingly slow. Much of the resistance to change had come from gunsmiths and part manufacturers, rather than from the engineers and designers of machinery. Even as late as 1854, Joseph Brazier the famous Birmingham gun lock maker was not convinced of the success of machine made parts. When giving evidence before the Select Committee on Small Arms in that year he was asked in connection with Colt's repeating pistol "What is your opinion of the statement, that the different parts might be thrown together into a basket, and taken out indiscriminately and fitted together"? He replied, "I do not believe a word of it". .11.

Brazier's attitude might be explained in general by the tension which had been created by the Board of Ordnance with their strict standards of inspection, and in particular by the failure of the Government tendering system to provide stable long term contracts for the gun trade. These factors had severely damaged the industry's confidence, resulting in lack of investment in capital equipment. Therefore, it would be surprising if many of the craftsmen grouped in small workshops and filing to gauge would have had the opportunity to gain first hand experience of the latest achievable accuracies of the new machine tools. Also, given the craft based nature of the gun trade, it would seem unreasonable to expect gunsmiths or skilled artisans to accept immediately the proposition that high levels of precision could be achieved without the use of a file. As the weight of physical evidence increased, through the publicised achievements of American and other machine tools, it would have been surprising if the traditional British craftsman, who had jealously protected the manual skills which had been handed down to him over the centuries, had not resisted change. The introduction of increasing amounts of machinery would most likely have been viewed as a threat. After all, many craftsmen would have already been aware, perhaps through rumours, of radical changes to working conditions when Colt's Pimlico factory opened in January 1853. Here the use of machinery in pistol manufacture had introduced unskilled workmen to the production of the weapon; the machines taking on the work formerly carried out by craftsman. This would no doubt have been viewed as a direct attack upon future livelihoods within the gun trade.

To illustrate the level of British understanding in areas of standardised manufacture Nathan Rosenberg has pointed out that Paxton's designs for the Crystal Palace structure in the Great Exhibition of 1851 had been based on producing prefabricated parts for glazing, guttering, flooring and general support, thereby heavily capitalising upon the principals of uniformity (Figs.12 & 13). This illustrates that knowledge of standardized parts had gained acceptance in the British building industry after the pioneering work in mechanical engineering by Bramah and others but not, seemingly, in the gun trade. As early as 1812, within the heavy engineering sector, Henry Maudslay's company was prepared "to furnish (upon reasonable terms) the most approved and complete Steam Engines, & when to send abroad provided with all necessary duplicates &c. of the wearing parts to ensure their perfect success in countries where mechanical assistance cannot easily be procured". .12. Here it can be seen that the principles and advantages of standardisation had been known and practised in Britain for at least forty years, although in a different branch of engineering from the gun trade. However, if the manufacture of Bramah's mass produced locks are taken into account the period extends backward into the eighteenth century. This, therefore, supports earlier findings, where it has been shown that powerful political forces were holding back the development of the technology in other areas of manufacture, notably that of military small arms. Nevertheless, it will be appreciated that the tolerances worked to for Paxton's building components can not be compared with the precision required for small arms production and of course standardised parts are not necessarily the same as parts that will readily interchange, the latter being the goal to which many engineers had worked and were working.

The American path to standardisation

In America, military weapon manufacturers did not suffer the same inhibiting conditions as their British counterparts. From early in the 19th century the National Armouries of Springfield and Harpers Ferry were able to take advantage of a government arms policy which was sympathetic to technological progress; in fact innovation was positively encouraged. Rather than rely on a private contract system which discouraged investment as had British "Ordnance", the American Government had realized that to achieve significant improvements in arms production their support of certain enterprising inventors was crucial to progress. For example, Thomas Blanchard acted as an "inside contractor" at the Springfield Armoury between 1823 to 1827, completing much of the later development work on his sequence of gun stock forming machines. Roswell Lee, the superintendent at Springfield, when explaining his reasons for having Blanchard on site, suggested that the exercise would "test the utility of the plan, & ascertain what can be saved by this improvement". Lee quite justifiably concluded the "principal object, is to bring the Machinery to the most perfect State". .13. Merritt Roe Smith, when discussing this particular initiative, astutely states "Since a private contractor could hardly be expected to underwrite such an expensive experiment, the superintendent through the United States had to shoulder the burden and, in a sense, subsidize Blanchard's project". .14. Roe Smith's observations, and further examples like the inventor John H Hall, being granted a "special contract" at Harpers Ferry to develop standardized and precision methods of production for his early breech loading rifle, can be viewed as some of the most significant differences between the American and the British Government's approach towards the development of mass produced small arms and interchangeable manufacture. .15. A later example of this type of cooperation between the American Government and the private sector ironically benefited British "Ordnance" when the Commission to America placed orders for machine tools with the Ames company in 1854 to equip the Enfield factory. The strength of cooperation between the State and the private sector can be seen and is graphically illustrated in the example of Mr Ames, who would not sign the British contract unless he acquired the services of Cyrus Buckland, Engineer to the United States Armoury at Springfield. Permission was quickly granted to temporarily release Buckland and the contract proceeded. .16.

While the American National Armouries were pursuing a policy towards uniformity and functionality in their weapon design, George Lovell under the British Board of Ordnance, whilst setting strict viewing standards for mechanical tolerance, had also directed his inspectors to examine the degree of finish on all weapons and parts. .17. While measuring mechanical tolerances against the pattern and checking with gauges was a reasonably accurate and scientific exercise, the viewer's assessment of standards of finish could only be a subjective judgement. From the many examples of the gun trade's rejected work as discussed previously, it would seem reasonable to conclude that "Ordnance" viewers were not only checking to gauge, but were making subjective judgements based on their own perceptions of pleasing aesthetic features. These refinements were in all probability a hang-over from the standards expected within the expensive sporting gun business. It will be recalled that much of the evidence given before the Select Committee of 1854 had demonstrated that niceties of finish were quite unnecessary, particularly when considering the treatment of the weapon under battlefield conditions. Spending extra time on a weapon or part during the manufacturing process to remove tool marks and other aesthetic aberrations by polishing and delicate filing would not have been conducive to "Ordnance" obtaining arms at the lowest possible price. The British gun trade was suffering from a whole raft of difficulties imposed by "Ordnance", which through its actions had postponed manufacturing modernity. It might be pertinent to ask how American engineers had obtained, developed, and implemented the ideas which gave them the lead in machine intensive small arms manufacture.

Technology diffusion

To maintain the continuity of the debate a brief look at the methods of technology diffusion and transfer is taken here. The subject of diffusion and transfer is taken up again at the end of this thesis, drawing together our investigations of the more subtle ways in which technical know-how was obtained and exchanged.

Like many investigations there are not always clear cut answers to questions. The reasons why a certain set of circumstances evolved or prevailed are often multifarious and complex. This is certainly true in the case of technology transfer and diffusion. How American engineers and entrepreneurs obtained the technology in the first place is probably best explained by the on-going process of the diffusion of skills, physical examples and ideas. The most likely channels for the communication of the emerging technology was through migrant craftsmen who had the opportunity to influence American engineers and industrialists. Charles H Fitch, (special agent on the Tenth Census, on the interchangeable system of manufacturing in the United States) asserted when discussing the American National Armouries in the early part of the century "the filers - skilled workmen - were then mostly foreigners". .18. Fitch would have had a good understanding of immigrant influence within the United States as his report, published in 1882, acknowledges assistance from senior U.S."Ordnance" officers and many of the household names in the machine tool and gun related industries. .19. Other routes for diffusion were open through the mobility of agents and salesmen who offered a range of plant and products. The export and servicing of such commodities would have provided further opportunities. Entrepreneurs and engineers from America made business trips to Britain and it would be unlikely that they returned home without gaining some knowledge of new developments in their particular field.

Haemorrhaging of British engineering and other technology had been felt in the 18th century. The problems were thought so great that by the early 1780s legislation was introduced so that "no skilled artisan or manufacturer was legally free to leave Britain or Ireland and enter any foreign country outside the Crown's dominion for the purpose of carrying on his trade". .20. However, this did not prevent the determined, as from 1783 to 1812 some 100,000 persons left Ulster for the United States. In 1811 H M Customs submitted reports on the emigration of Bristol glass workers and Lancashire cotton workers, while in 1812 they "...relayed an anonymous letter about workers from the Birmingham arms manufacturers taking their tools with them to America". .21. Of course diffusion took place through less obvious routes such as demonstrations, lectures and technical publications by learned bodies. Other publications were readily available, such as the Edinburgh Encyclopaedia and Rees's Cyclopaedia. These works gave illustrated diagrams with detailed descriptions of machinery and its functions.

Marc Isambard Brunel fled his native France to America where he worked as a civil engineer, eventually becoming Chief Engineer of New York. He left America in 1798 for England where he was able to get his block making machinery built by Henry Maudslay. It would be difficult not to imagine that Brunel had in some way acted as an international conduit for ideas. Brunel's association with Maudslay who had previously worked for Joseph Bramah is further evidence of the diffusion mechanism. In turn, the distinguished engineers, Richard Roberts, James Nasmyth and Joseph Whitworth had all been employed at one time by Maudslay. .22. It will readily be seen from these examples that apart from engineers travelling to different countries, the profession was somewhat incestuous. There are many such recorded examples of this type of skill transfer and diffusion at all levels of the trade on both sides of the Atlantic. This helps to explain why similar ideas and designs occurred in different parts of the world, apparently unconnected, the hidden relationship being that of the mobile craftsman, engineer and entrepreneur.

American inventors and developers in the area of machinery were no different to their British or European counterparts who had either consciously or unconsciously taken the evolutionary approach to technological development. There is little supporting evidence in the field of technology to suggest that invention, solution finding and product development had come about through a single revolutionary approach to a particular problem. In most instances invention and problem solving had been tackled and refined by many people making a contribution, often over a period of years and, on occasions, approaching the task from a different stand-point. This view is supported by Fitch in his 1882 Census Report when he discusses the development of interchangeability. Here he refers to it as "a gradual process, extending over a considerable period of time. Sample guns, with parts to interchange had been made in France as early as 1717, ..." .23.

Clear evidence of diffusion can be observed from a cursory glance at the shape of a 17th century French musket lock plate and hammer. It will be seen that the style has carried on and was still being used extensively in middle 19th century small arms, both in Britain and America (Figs. 14, 15, and 16). Further evidence of the diffusion of ideas can be seen in machine tool design. If the main principle is examined of copying a pattern as demonstrated by the circa 1822 Blanchard lathe for turning gun stocks (Fig. 17), there is a striking resemblance to the technology and principles employed in the "machine for making dead eyes" (Fig. 18) invented by Marc Brunel, as well as other machines used in the production sequence at the Portsmouth block making factory in 1805. However, David Hounshell dismisses the idea that Blanchard could have been influenced by Brunel when he wrote "Although Blanchard clearly did not draw inspiration from Brunnel's (sic) machinery for his fundamental gunstock-turning lathe (because the blocks were not irregularly shaped), it is entirely possible that he used Brunel's ideas for mortising and recessing". .24. That somehow tracing a pattern, which Hounshell did not believe to be "irregularly shaped", negated Blanchard's ability to have derived his inspiration for Brunel's copying principle seems a curious conclusion for him to have reached. For example, the groove cut in a wooden block by Brunel's dead eye machine is in fact irregular. However, this is not the issue to be considered when evaluating the principle of Blanchard's machinery. It is the concept of tracing and following a pattern which is the crucial factor.

Apart from the machinery under discussion, there was ample opportunity for Blanchard to have been inspired and to exploit the many ideas of copying which were around at the time. In 1799, when living in America, Marc Brunel had obtained a patent for a

"Machine for writing with two pens", based on the pantograph principle. Some months later, after arriving in England, a British patent for a machine was granted "for making three or more similar writings or drawings at the same time by the same person". Brunel arranged for the machine to be manufactured by John H Farthing in London and a number were exported to America in 1801. The machine was advertised by Pierre Martin Stollenwerk and Nephew of New York, with the offer to instruct purchasers in its use. .25. With this and other copying machines and ideas freely circulating on both sides of the Atlantic, it would seem unreasonable to assume that an engineer of Blanchard's calibre would not have had his curiosity raised sufficiently to investigate the principle.

Although in his text Hounshell refers to Rees's Cyclopaedia, he has probably failed to notice the significance of the machine for making dead eyes. These devices, although produced on the Brunel Maudslay machines at Portsmouth were not mechanically the same as the ship's pulley block and performed a different function. Used in pairs, the dead eyes formed part of a system which provided anchor points for the shrouds, giving support and stability to the ship's masts. Examining the dead eye reveals a groove cut around the circumference of a formed wooden block. The shape produced can be likened to a thickish plate with a bump on one edge, making it irregular. Brunel's dead eye machine worked on the copying principle by tracing a pattern. Referring to the diagram in Rees's Cyclopaedia the crucial part of the machine's action is described thus:-

> ...The depth to which it is permitted to cut is determined by

> roller, d, situated at the end of a rod which is fitted on the axis, S, of the frame, R S, and attached firmly to the frame by arch, V; in which is a groove to receive a clamp screw, which gives the means of fastening it at any point, and the roller then becomes a part of the moving frame R S. The roller applies itself to a pattern, on a shape-wheel, W, fixed on the spindle, and turning with it. Its figure is circular, except a projecting knob on one side, w, as shown by the dotted lines in [fig.18.] ...The screw r, at the end of the slider, regulates the position of the roller which applies to the shape N, and thus adapts to the thickness of the dead eye. The operation of this adjustment will be understood by referring to the operation of the shaping machine. The shape, N, is readily changed, to make different sizes, by introducing others of a different curvature ... .26.

From the information relating to Bramah's patent (mentioned above) and from the physical and descriptive evidence of Brunel's block making machinery (which the writer has examined), it is clear that both the technology and ingenuity was available at the beginning of the 19th century in Britain to manufacture gun stocks by machinery. What was lacking was the motivation to do so.

Hounshell, in dismissing the possibility of Brunel's influence on Blanchard, has drawn on information from the Portsmouth block making articles of Carolyn C Cooper and the late K R Gilbert. While both articles give an excellent account of the Portsmouth block making machinery, neither illustrates or describes the machine for making dead eyes. Gilbert lists the two models of machine employed (small and large dead eye machine) but nothing more. While it can not be conclusively proved that Blanchard took his ideas directly from Brunel, it would be difficult to imagine that he was unaware of the technology employed in his machinery. At the time, there was a sufficiency of published information describing in detail the Portsmouth machinery. .27.

Was American industry fully mechanised by the 1850s?

An examination of the American Government's 1882 Census Report on Fire Arms by Charles Fitch will show that Blanchard had built a gun-stocking machine using the copying principle for the Springfield armoury in 1822 (Fig.17), based on his 1818 prototype. This machine was only for the rough turning of gun stocks. It was not until 1827, after a period of development, that a much more sophisticated system of sixteen sequenced machines evolved, some twenty two years after a similar process had been installed at the naval dockyard at Portsmouth. Fitch lists the operations of the individual Blanchard "stocking and turning machinery" as follows:-

> sawing off stock, facing stock and sawing lengthwise, turning stock, boring for barrel, turning barrel, milling bed for barrel breech and pin, cutting bed for tang of breech-plate, boring holes for breech-plate screws, gauging for barrel, cutting for tang of breech-pin, forming concave for upper band, dressing stock for and between bands, forming bed for lock plate, forming bed for interior of lock, boring side and tang-pin holes, and turning fluted oval on breech. .28.

It will be noted from the sixteen operations listed by Fitch above that the last one is in fact a metal-working rather than a wood-working procedure.

According to the Fitch Census, it would seem that American small arms manufacturers were not as highly mechanised as is commonly thought until the 1850s. It may be worth pointing out that the levels of interchangeability achieved in America, while coupled with machine tool production, must not be seen as linked to a rapid implementation of mechanisation throughout that country generally. The private armouries, like those in Britain, had not in general invested in large quantities of capital equipment.

Fitch goes on to explain:-

> Apart from all consideration of the earliest usage of specific machines, it must be said that their introduction did not make itself felt as a great industrial agency until within twenty-five years past, in instance which it may be stated that in 1839 there were at the Springfield armoury about six men to one machine, and the ratio at other works seems to have been equally large; for of the private armouries most reputed for early improvements one is stated at the time to have but a single milling machine, and that a rude one; and at another armoury a single gang-saw profiling-machine was the principal stocking machine in use. It was some fifteen years later before the manufacture of milling, edging, and other important gun machinery was conducted on a scale sufficiently extensive for the general outfitting of large armouries. .29.

If Fitch is correct in his report of 1882, when he makes the observation that machinery did not have a strong impact upon industry "within twenty-five years past", this might help to explain why Britain had to provide the American armies of the North and South with large quantities of arms during the Civil War of 1861 - 1865. Of course another possibility could have been that it takes time for any manufacturing facility to organise an increase in production capacity. The only way to satisfy demand rapidly is to obtain product "off the shelf" from elsewhere. In the period 1861 to 1864 the private gun trade of Birmingham and London alone supplied over one million weapons to America. The conflict appears to have galvanized the American arms manufacturers into overdrive as, according to Goodman, one reliable observer writing in August 1865 suggested that Springfield had doubled its output over the last two years of the War to 1000 muskets per day. It was also suggested that by the end of the War the private factories were capable of matching Springfield's production output, the combined capability being 60,000 rifles per month. .30.

While it is accepted that the "Committee on the Machinery of the United States of America" visited a number of diverse manufacturing sites in 1854 and viewed a reasonable amount of machinery in operation, it must be remembered that their visits were specifically targeted at factories so equipped, as they particularly wished to observe mechanised production methods. From their report it is not possible to learn what proportion of American industry had invested in large scale mechanised production.

Like Joseph Whitworth before them, the Committee were most impressed with the level of mechanisation in the production of gun stocks observed at the Springfield armoury, a system not in use in Britain at the time. The picture painted in the minds of later historians and others, particularly regarding the novelty of the mechanised Springfield system of gun stock shaping, would seem to have been influenced by the reports of Whitworth and the Committee on the Machinery of America. This has probably created the false perception that United States industry was generally far more mechanised by the middle of the century than it really was. The excitement communicated by those who viewed such novel machines appears to have induced powerful and lasting images. A systematic processing of a product through a sequence of machines would have been relatively easy to comprehend even for the inexperienced observer. The visitor to the factory would have witnessed the product developing through its various stages from a roughly shaped block of wood to an easily recognisable gun stock. This is perhaps why this particular example of mass production has received so much publicity, not only in the nineteenth century but also from later twentieth century researchers of the subject. It is not too difficult to imagine why people may have accepted the notion that American manufacturers were highly mechanised, mainly because of the glowing reports of the gun stock machinery in operation. Evidence suggests that, by the middle of the century, this machinery had mainly been installed at the government armouries of Harpers Ferry and Springfield, where it had been developed and perfected. Also by the 1850s, and no doubt encouraged by their close relationship with the U.S. Government, contractors like Ames, Robbins & Lawrence, Sharp and Colt had invested in mechanised manufacture. In contrast to their American counterparts, the British private gun trade did not have the luxury of a sympathetic government. Perhaps, if they had had such support, the industry would have been encouraged to developed mechanised methods of production much earlier.

While the issue concerning the relatively restricted amount of mechanisation within the small arms industry of the United States seems to have been overlooked by many commentators, this does not detract from the fact that American engineers had embraced, developed and persevered with the technology of interchangeability, bringing it to an advanced state by the middle of the century.

For the firearms industry in America to have taken advantage of any cost benefit which might have been derived from interchangeability using mass production techniques would have required large scale manufacturing plant capable of processing substantial orders of standard product. Of course such plant would have required a major customer or customers providing the stability of continuing long-term orders. By the middle of the 19th century, apart from the United States Government, these conditions were the exception rather than the rule in America. Taking the 1860 Census statistics, Harold Williamson has revealed that:-

> ...there were some 239 establishments producing firearms which employed a total of 2,056 workers, on an average of less than nine per establishment. Only in the New England states and especially in Connecticut was there any trend towards large size concerns. In the latter state, nine producers employed around 969 workers. Of this number some 369 worked in Colt's factory at Hartford and another 300 in the Sharps factory operated by Robbins & Lawrence in the same locality. But these two factories had only recently been established - Colt's in 1853 and Sharps' armory in 1854. .31.

Spreading the word

Further support may have been given to the notion of a highly mechanised American industry when John Anderson, in 1858, gave a paper to the Institute of Mechanical Engineers entitled "On Some Applications of the Copying or Transfer Principle in the Production of Wooden Articles". Anderson refers to his visit to America with the Commission in 1854 and comments:-

> ...the writer was much struck with the many simple and ingenious contrivances there introduced, in order to apply the copying principle in connection with ordinary hand-lathe operations, where generally in this country more would be dependent upon the skill or attention of the turner or upon special machinery. For example, the production of articles where there is repetition and which are to be turned in a common lathe, the application of certain very simple additions tends greatly to facilitate the operation and to enable the operator to dispense with the usual measuring and gauging and the use of callipers, which generally occupies so much time. .32.

Anderson also refers to the Blanchard copying lathe several times in his paper and devotes time to explain how "In the Small Arm Factory at Enfield the intricate piece of mechanism, the gun stock, is produced entirely by machinery". .33. The respected British journal The Engineer, ran a series of articles in 1859 describing the manufacturing processes carried out at the Royal Small Arm Factory at Enfield. Praise was given to the American machinery and the reader could be forgiven for thinking that the system was quite common in the United States. The following short description illustrates the point:-

> ...the Government instituted inquiries which eventually led them to adopt a most beautiful arrangement of machinery perfectly adapted to the purpose in view. This arrangement is on the general system in use in the United States, and its present degree of perfection has been arrived at by the united and ingenious efforts of various mechanical engineers. .34.

The fame of the American system was also spread by the eminent British engineer and machinery manufacturer Thomas Greenwood. In 1862 he presented a paper "On Machinery for the Manufacture of Gunstocks" to the Institute of Mechanical Engineers. Replying to the Chairman's question, "where the original machines for the manufacture of gunstocks had been used, from which the machinery now described had been derived"? Greenwood replied, "the gunstock machinery was of American origin, and the American government had been occupied for the last twenty years in perfecting the manufacture of guns by machinery at the armouries of Springfield and Harper's Ferry". .35.

Lovell evaluates gun stock machinery

George Lovell, for reasons not fully understood, is not forgiven by Howard Blackmore for his apparent reluctance to introduce machinery for the manufacture of gun stocks into the Enfield factory. Blackmore points out that over the years Lovell was aware of a number of inventions which may have assisted in the production of gun stocks but these were generally ignored. .36. However, one such invention by the Portuguese Ignacio de Barros was examined by Lovell at Mauberge in France after the former's untimely death from cholera.

In August 1849, the Secretary to the Board of Ordnance, R Byham, received a letter from Mon. de Barros, stating that "This machine will produce by a Model any article required in wood with great perfection and rapidity. It makes 6 gun stocks at one time and in perfectly uniform, and exactly according to the model, requiring for this purpose only the attendance of 2 men". While initially the description of the machine appears to be superior to Cyrus Buckland's improved Blanchard lathe (Fig.19), reading further down the letter suggests that this is not the case when compared to the more comprehensive process in operation at the Springfield National Armoury in the early 1850s. According to the inventor "A workman in France, taking a stock made by the machine will fix the barrel and lock and finish again completely in 3.5 hours. By the old system of making the stock by hand, the same operation will take 12 hours". .37.

When the Committee on the Machinery of America visited Springfield in 1854 they reported, "the time required to pass a gun-stock through the sixteen different machines varies from twenty minutes to half-an-hour". Admittedly this did not take into account any allowances in down-time for tool sharpening or machine adjustment during a typical ten hour day. It was also reported that it took a single workman a further 3.5 minutes to assemble the complete rifle. Research would suggest that to achieve this rate of assembly the lock would need to be supplied as a sub-assembly, rather than in its separate component parts. .38. However, Carolyn Cooper has pointed out that these times did not take into account hand finishing, which with assembly amounted to "3.5 hours per stock in 1843" and "in 1854 was taking slightly less than 1.5 hours". .39. It is not absolutely clear from the correspondence if the 3.5 hours quoted by de Barros included hand finishing. Even if hand finishing was included within the production timescale, and accepting that the completion of the gun stock was a marked improvement upon manual methods, it is clear from the performance of the machine, as reported by Lovell, that it had not been fully developed.

A further letter, dated 8/8/1849, to the Board of Ordnance from de Barros's agent in Britain, B P Pargana, discusses two sample gun stocks made by the machine. The agent freely admitted that the furniture (the metal parts fitted to the stock) had been "executed by hand". What is most interesting and revealing about this letter is that George Lovell had written on the back (8/8/1949), making the point that, although he has examined one of the gun stocks, he is unable to form an opinion of the machine without seeing it at work. Lovell's writing allows the reader an insight into his thoughts, showing that he is not opposed to the introduction of wood-working machines as Blackmore has implied. In fact, it is clearly demonstrated that he has a first rate understanding of the benefits to be obtained from such machinery when he further commented:-

> I have no doubt however from my own experiments and observations that a large portion of the woodworking of musquets may be more uniformly shaped by machinery and at very greatly less cost than by hand - and if the Honourable Board should think fit to pursue an enquiry of this nature I would request their authority to proceed to Paris to examine Mr Barros's invention - when I shall be able to report in detail upon its capabilities. .40.

In Lovell's report of 2nd October, he describes his examination of the de Barros machine which he observed working at the establishment of Dandoy, Milliard Lucy & Co. Coincidentally, like the earlier devices which used the copying principle, the machine used a cast iron model of a French gun stock as the pattern. Highlighting the point that the channel for the rammer had to be bored by hand and the lock furniture had to be let in, Lovell observed, "no part of such work being provided for by the machine which in fact is only capable of roughing out". Illustrating his considerable understanding of the subject Lovell went on to say, "a machine or set of machines for making musquet stocks must go much further and finish more completely than these". He then identified other major problems with the machinery:-

> The uniformity which is so much valued in machine made work is not secured because the cutters with the speed they work at must soon be altered in form by sharpening; and the models by friction - that sharpening of tools and replacing of models can only be done by workmen on high wages: - The circular saws between themselves and with reference to the floating guides must all be kept at <u>exactly</u> [Lovell's underlining] the same diameter after they have been re-fitted or no uniformity of shape will be maintained in the stocks... .41.

Gun stock forming machinery was never introduced into the Enfield factory until the machinery arrived from America in the mid 1850s. Lovell during his time as Inspector of Small Arms had not found any suitable stocking machinery and, as explained earlier, "Ordnance" were not placing large orders for new arms in the 1840s. Furthermore, the maximum annual output of Enfield at the time was only a few thousand weapons. .42. Therefore, it will be appreciated that the capital expenditure to install such a system would not have been justified. Apart from the cost of the machines, there would have been extra expenditure on buildings and a power source. Of course it must not be forgotten that Enfield remained a minor producer of small arms until the Crimean War, when the conflict effectively released the private gun trade's grip on military weapon manufacture, allowing "Ordnance" to go into direct competition against them, eventually becoming a major producer of small arms. Up until then, the vast majority of arms production was still in the hands of the private gun makers who grudgingly served the contract system operated by "Ordnance". Even if Lovell had been successful in finding machinery which was efficient and cost effective, under the politically sensitive conditions created by the private sector it would have been extremely difficult for "Ordnance" to have installed new plant for stocking without causing a major outcry.

Management of a scarce resource

One of the major drawbacks to the continuous production of arms in Britain was the supply of fully seasoned walnut gun stock blanks. The seasoning process was lengthy and could take up to three years to complete (some estimates have suggested as much as five).

In February 1848 Lovell wrote a report after visiting Davis & Symington's in London, where he examined the process of "desiccation of wood and other substances by the application of currents of heated air". Lovell reported that the process consisted of having a ventilated room 24'x18' and 15' to the roof, formed with double walls and doors to "prevent warmth escaping laterally". The floor was constructed of York paving on a bed of concrete. Placed in one corner of the room was a stove furnace which had a 26' chimney. Basically the system consisted of a fan located in an external wall which was driven by a strap from a drum in an adjoining building. Air was drawn in by the fan and fed through an iron pipe which passed in a series of loops within the furnace. The furnace heated the air which was then fed to ducts in the floor from which it escaped upward through perforated iron plates. Wood for drying was placed on racks within the chamber and by the action of convection the warm air rose around it carrying the expelled moisture through ventilators in the building's roof (Fig's.20 and 21).

Lovell, in testing the system, took thirty gun stocks that were partly seasoned (fifteen months in store) and thirty that were "quite fresh cut and full of sap". These were carefully weighed and put in the drying room for ten days at a temperature of 110 to 114 degrees Fahrenheit. From this experiment the following results were obtained and recorded:-

Stocks.	Weight before process.	After process.	Weight loss.
30 Half seasoned.	240lbs. 14.5ozs.	206lbs. 13ozs.	34lbs. 1.5ozs
30 Fresh.	295lbs. 10.5ozs.	207lbs. 1.5ozs.	88lbs. 9ozs.

The sixty stocks were then exposed to the air in the stock store and in the first seven days they had increased in weight by 2.5%

as they absorbed moisture from the atmosphere. Lovell commented, "as might be expected from the hygroscopic state of the wood". But over the next eighteen days the stocks had only increased by 1.5%. Further experiments by Lovell found that by exposing for thirty days, six stocks dried naturally and six dried by "the process", the former increased in weight by 3.6% and the latter only 1.55%. Not allowing the experiment to rest there, Lovell took it to the next stage by dispatching the stocks to the trade without informing them that they had been hot air processed. In his report he gives the reasons for his action as follows:-

> With a view to collect the opinion of working men upon the state of the wood; I directed 15 of the desiccated stocks to be set up into musquets in London, 15 at Birmingham and 15 at the Royal Manufactory at Enfield. My own view of the subject is that by quickly inspissating the albumence and juices of the wood at the same time that humidity or mere water is driven off, the wood is rendered tougher than when dried more slowly in the natural way. ...but the experiments may have satisfied me that the process offers by far the best means of seasoning wood quickly that has yet come under my observation; and I think that it may be adopted with every prospect of advantage to the Services: more especially at the present moment when the demand for dry musquet stocks is so pressing. .43.

As a result of Lovell's successful experiments, a drying chamber was built at Enfield, the work being completed in September 1848. However, Lovell's recommendation to build the chamber was not immediately accepted by "Ordnance". It took several months of frustrating correspondence between Lovell, the Board of Ordnance and Davis & Symington's (known as the Patent Desiccating Company) before agreement was reached on costs and royalty payments associated with the process. Specifications for the chamber were altered, the Inspector General of Fortifications expressed the view that the "...chamber should be isolated and not built against end of water wheel house". The fan had to be increased in size to double as substitute bellows for the smith's forges, the power for this being taken by a belt connected to the water wheel, saving the cost of a steam engine. Costs increased from £630 to £710 as the end wall brickwork expanded to 18 inches. The estimated time to complete the work went from six to eight weeks.

Towards the end of the correspondence, Lovell emerges as the clever politician, determined to get his way by bringing the matter to a head. After putting forward a range of options, the Patent Desiccating Company offered a compromise solution by dropping their demand for a substantial payment to use their process. The Company now proposed a package which included a corrugated roof for the chamber rather than an asphalted one. Lovell wrote to the Board on the 3rd April stating "I do not think that the sum now asked by the Company is unreasonable; and I would therefore take the liberty to advise that their offer be accepted". A few days later Lovell was again writing to the Board and playing his "political" trump card:-

> I am under the necessity of suspending the issue of materials for setting up Extra Service Musquets at the Tower, in consequence of the store of seasoned gun stocks being entirely exhausted and that there are no more left at Birmingham than will meet the issues for about three weeks. .44.

Twisting the screw a little tighter, Lovell recommended to the Board that 15,000 stocks be sent to the Patent Desiccating Company for drying at £12.10s per thousand, total cost £187.10s. This quantity Lovell believed would be sufficient to bridge the gap until the erection of the chamber at Enfield. Pushing home his advantage Lovell made the point:-

> I would beg the Hon Board's earliest decision upon this latter point; because it would be otherwise absolutely necessary to continue the seasoning by the Company to at least a number of 60,000 more in the present financial year at an expense of not less than £750. The Board will perceive from this that the adoption of the proposition of the 3rd instant will prove less expensive even within the present year. .45.

From the correspondence it would seem fair to conclude that it was not the supply of gun stocks per se that presented the "bottle-neck" to arms production but the supply of seasoned stocks. It would have been difficult, if not impossible, for "Ordnance" to always accurately calculate their annual requirement of fully seasoned wood to meet every unforeseen contingency. The average natural curing time for a stock of approximately three years would have made the difficulty more acute. Therefore, the installation of the desiccating chamber at Enfield would have provided one of the most significant breakthroughs in the ability to mass produce small arms, by dramatically reducing material acquisition times for the gun stock. Of course having a reasonable quantity of seasoned stocks in store would also have allowed "Ordnance" greater flexibility in the planning process, making the annual calculations for arms less traumatic as one of the major "bottle-necks" would have been effectively removed.

A gun stock incident related to supply problems

At the time when negotiations for the desiccating chamber were taking place there were serious complaints from one of the major gun stock contractors, Pirlot & Simonis about the "misdirected zeal of the viewers". The incident which is about to be discussed had no doubt helped to create the shortage of gun stocks alluded to above by Lovell.

In an effort to resolve matters, M. Simonis came to England seeking redress and to investigate personally why problems had occurred with the first fourteen cargoes shipped from France between 1846 and 1847. Evidence suggests that, due to insufficient warehouse space, deliveries of stocks to the Tower were ordered by the Chief Clerk, Mr Poritts, to be placed in the moat. Here it was reported that many deteriorated and "others reduced wholly unserviceable". Clearly this was the fault of "Ordnance", not the contractor. There is also a revealing reference in the correspondence that there was a "...great difference between the rejections at the Tower and Enfield". This might suggest different storage arrangements between the two sites or the possibility that the viewing department at Enfield was applying a different or more lax inspection standard than the Tower. However, from the official report of the incident it is known that the Principal Viewer at the Tower, Charles Philcox, agreed to be slightly "...more liberal" with the view at the time of M. Siminos visit. .46.

By way of compensating the contractor, the matter was finally resolved, perhaps somewhat naively, by altering to a small extent the terms of future viewing by the introduction of an additional class of gun stock, "extra superior". For this, the contractor was paid a higher price. Unfortunately, some years later the episode was to lead to the severe criticism of George Lovell by the Master General of Ordnance, Lord Hardinge, perhaps a little unjustly, for over-stepping his authority. Lovell's son Francis, who at the time was the Assistant Inspector of Small Arms and had the responsibility for dealing with the contractor, was removed from office. .47.

The events surrounding the shortage of seasoned gun stocks, which had no doubt been exacerbated by the poor storage facilities at the Tower, would appear to be directly related to the badgering of "Ordnance" by George Lovell to build the desiccating chamber at Enfield. It would seem more than coincidence that Lovell senior, in August 1847, while trying to resolve a number of problems with the contractor Pirlot & Simonis by relaxing the view, was at the time, almost certainly communicating with Davis & Symington. On the 23rd October 1847 results of a ten day experiment on behalf of the Board of Ordnance were published by Davis & Symington concerning the seasoning of gun stocks. As these experiments would have taken time to organise, the episode demonstrates the strong likelihood that Lovell was desperately trying to improve the supply of seasoned wood and was probably driven to examine every means possible to resolve the situation. Having the ability to season gun stocks fast would have almost eliminated the necessity to have wood standing outside and deteriorating, which in turn would have increased the amount of material passing the view. These would have been considerable goals to achieve in the production of small arms by any standard.

Scarce natural resources provoke differing technologies

The available evidence suggests that Enfield, certainly as early as 1848, was the only armoury of note employing a desiccating chamber on site. When corresponding with Carolyn C Cooper, acknowledged for her research in the area of 19th century mass production machinery and processes relating to wood, she commented "from your description of the kilns at Enfield; sounds as if they were more "modern" than Springfield". However, in spite of the considerable work by American historians on the Springfield armoury, no evidence has yet emerged to suggest that any form of kiln drying or steam curing was carried out on the premises. .48. Perhaps the availability of a plentiful supply of home grown timber in America caused the authorities to believe artificial drying unnecessary. While it might be thought that climatic conditions in certain parts of the United States were better than Britain, this could not have been the reason for not employing a drying chamber as the natural curing time for wood in both countries was similar.

In Britain, before the middle of the century had been reached supplies of home grown walnut had become almost exhausted and imports were obtained from the Continent, the bulk coming from Italy. The different approaches adopted by British and American "Ordnance" to the assemblage of gun stocks would seem to support Rosenberg's argument that "In a highly resource-abundant environment such as the United States, it made excellent economic sense to trade off large doses of abundant raw material inputs for the scarcer factors of capital and labor". 49. Of course, there may have been other factors which had caused the American National Armouries not to employ desiccating chambers like Enfield. For example, the extra space required to store the quickly dried wood and the cost of fuel to run the drying chamber may have been prohibitive. Evidence of Springfield's plentiful supply of suitable gun stock timber can be observed in the report of the 1854 British Commission to America when they wrote:-

> The stock of the American musket is made of black walnut, which grows in very large quantities in Pennsylvania, from which State it is procured by the persons who supply the United States' Armory with stocks in the rough. The United States' Government do not enter any contracts to obtain them, but whoever likes to bring a quantity to the armories can obtain 28 cents each for them, provided they pass the Government viewer. .50.

This report provides a further clue to the different way in which the American National Armories procured wood for gun stocks than that of their British counterparts. The system of "whoever likes to bring a quantity to the armories" might suggest that the bulk of the material was held by the suppliers, allowing a flexible working float to be kept on site. This would have had the added advantage of keeping to a minimum costly warehouse space, while at the same time placing the risk upon the supplier for deterioration in store. In a way, this system of wood procurement might be likened to a rudimentary form of "just in time" (JIT) materials management. However, an article published in July 1852 about Springfield provides contradictory information by suggesting that "...an immense store of it [black walnut] is kept on hand at the Armory - sufficient in fact for four years' consumption". .51. Therefore, it would appear that the Commission suggesting "whoever likes to bring a quantity to the armories" meant nothing more than the contractor routinely keeping walnut supplies topped up (presumably with green timber), as the armoury drew its normal production quantity of seasoned wood from store.

Invented elsewhere, developed in America?

There seems little doubt that American engineers had evolved and developed what was to become known as "the American system of manufactures", leading to accurate standards of weapon interchangeability. To suggest however that they were the sole inventors of such a system cannot be supported by examining the available evidence, as the basic concepts and the technology was "borrowed" or diffused from Britain and Europe. Working through the Government procurement system, the American engineers had taken an idea, perfected it and made it their own.

After the Great Exhibition of 1851, and because of the exhibits from the United States, there were many in Britain who believed that high levels of mechanisation were characteristic of American manufacturing industries in the early 19th century. However this image can not be sustained. Fitch was able to examine American industry from the closeness of the 1880s, where he observed that mass production techniques employing interchangeability had not become widespread until at least the middle of the century. Leadership in the technology of mass production had come mainly from the government armouries where the techniques had been pioneered and developed. Here Fitch has argued that it was only such establishments that were capable of large and assured demands which were the "...prime conditions of a uniform system". .52. However, Fitch has reminded us that uniformity as recognized by the 1880s, was somewhat different from the perceived view in the early part of the century when he states:-

> If gun parts were then called uniform, it must be recollected that the present generation stands upon a plane of mechanical

> intelligence so much higher, and with facilities for observation so much more extensive than existed in those times, that the very language of expression has changed. Uniformity in gun-work was then, as now, a comparative term; but then it meant within a thirty-second of an inch or more, where now it means within half a thousandth of an inch. .53.

This observation by Fitch gets to the heart of the debate carried on by historians in recent years over what really constitutes interchangeability. Numerous articles have been written and scholars like Robert Gordon have provided a wealth of scientific evidence to show that hand finishing of musket parts persisted for much longer than originally thought. Many discussions regarding interchangeability centre around whether it is possible to detect file marks on a part, which would indicate that the machine tools of the day were not capable of bringing the component to a precise standard without having to resort to hand finishing. .54. Providing the parts fit the gauge and interchange well and the output of the factory is not affected in either quantity or cost by hand finishing, then the niceties of the debate provide only an academic piece of detective work. Even today, any production manager worth their salt would try to recover parts by hand finishing had they not reached the required standard when coming off an automated process, providing of course the action was more cost effective than scrapping the material. One might contemplate situations where tight contract times were specified which included penalties for late delivery or, in the case of arms manufacturing, where production schedules had to be met in the event of war.

While many people from the position of the late 20th century see the development of British technology and other ideas by the American engineers and manufacturers as part of a long series of events, culminating in even greater losses to British engineering pride and expertise, there is a point of view which suggests that Britain was in fact exceedingly fortunate. To have someone else take on the costly risks of a major research and development programme (which is what the American Government armouries had effectively done) can often help divert scarce resources towards other much needed projects. While this approach may not have been deliberate on the part of the British Government, they had achieved considerable savings from the purchase of an America tailor made system to manufacture the Enfield pattern 1853 rifle, along with experts to install the machinery and to instruct the work-force. This episode had effectively given Britain a unique opportunity, as it had created a breathing space which not only allowed "Ordnance" to select the latest state of the art production system but also helped to focus attention on new ways of managing the scarce supply of walnut through the introduction of the desiccating plant. There was also a further advantage for "Ordnance". As the desiccating process did not rely on a system of machine tools it had not posed a threat to the livelihoods of the independent gun trade by taking away work. "Ordnance" had increased its influence over the manufacture of small arms without apparently rocking the private sector's boat.

The research and development role adopted by American engineers leading to the system of interchangeability had, in a way, allowed the British "Ordnance" to maintain a low profile and not be seen as a major competitive threat to the private gun trade. As debated earlier, even the relatively modest role of the Enfield factory had caused Parliamentary pressure to be brought by the private gun trade thus keeping "Ordnance" production to a minimum until the influence was broken by the Crimean War. Although it can be said that the British Government had bought customized "off the peg" mass production machinery from America, developed at no financial cost to themselves, it could also be argued that allowing the technology to evolve in the United States had deprived the British engineering fraternity of hands-on experience. However, there is evidence to suggest that British machine tool companies like Greenwood and Batley gained from this transaction, as they were able to improve, adapt and modify the American designs for other markets. So, in a way, the technology which had diffused from Britain to America at the beginning of the century returned in an improved state towards the middle and was destined to spread further afield through enhancement and modification.

NOTES

.1. Gilbert, K R, The Portsmouth Blockmaking Machinery, HMSO, (London, 1965) pp.1-4; see also Rees's Cyclopaedia, Strahan & Preston, (1819) pp.5-24, plates 1-7; also Carolyn, C Cooper, "The Portsmouth of Blockmaking", Technology & Culture, Vol.25 No.2 (April 1984) pp.182-183
The average 74 gun warship needed almost 1000 pulley blocks for the handling of sails and the positioning of guns. The Royal Navy required in the order of 100,000 of these devices each year. Bentham, who already had an appreciation of wood-working machinery, no doubt saw an opportunity of solving the Navy's needs almost overnight. Prior to Bentham's initiative, the Navy had been supplied with pulley blocks by Taylors of Southampton from around the middle of the 18th century. This family firm had over the years pioneered improvements in the manufacture of blocks by mechanising certain turning and sawing operations, first by horse power and then by water power. In fact, Walter Taylor is said to have invented the circular saw, while his son Samuel in the 1770s had standardized and reduced the material content of the ships blocks supplied to the navy.
A comprehensive account of the working of the block making machines can be found in Rees's Cyclopaedia of 1819.

.2. McNeil, Ian, Joseph Bramah: A Century of Invention, 1749-1851, David & Charles, (Newton Abbott, 1968) p.46

.3. Blackmore, Howard L, "Military Gun Making in London and the Adoption of Interchangeability", Arm Collecting, Vol.29, No.4 (November 1991) p.118

.4. Letter in possession of author from Chartered Patent Attorney, Ian Fleming, (21/3/94)

.5. Goodman, John D, "The Birmingham Small Gun Trade", in Samuel Timmins Ed., Birmingham and the Midland Hardware District (London, 1866), pp.392-393.

.6. Bramah, Joseph, "Machinery For Forming Gun Stocks etc" Patent No. 2652, (1802)

.7. Op.cit., McNeil, pp.44-45

.8. Rosenberg, Nathan, The American System of Manufacturers, Edinburgh University Press, (Edinburgh, 1969) pp.16-17

.9. Hounshell, David, From the American System of Mass Production 1800-1932, John Hopkins University Press, (Baltimore & London, 1985), pp.51-61.

.10. Ibid., pp.51-61

.11. House of Lords Record Office, London. Report from the Select Committee on Small Arms, Vol. XV111-1854, evidence of Joseph Brazier, pp.243-244

.12. Evans, F T, "The Maudslay Touch", Transactions of the Newcomen Society, Vol.66, 1994-95, p.157

.13. Smith, Merrit Roe, Harpers Ferry Armoury and the New Technology, Cornell University Press, (London, 1977), pp.134-135

.14. Ibid., pp.134-135

.15. Ibid., pp.184-185

.16. Lewis, James H, "The Quest to Bring the "American System" to the Enfield Armoury", Tools & Technology, Fall 1995, p.4

.17. Report from the Select Committee on Small Arms, Op.cit., Vol. XV111-1854, pp.488-489

.18. Fitch, Charles H, Extra Census Bulletin, "Report on the Manufacture of Fire Arms and Ammunition", Department of the Interior, (Washington 1882), p.7. Also see, Terry Coleman, Passage to America, Hutchinson & Co. (London 1972) pp.294-303. Coleman uses not only 19th century emigration figures from the U.K. to America which he explains are probably under estimates but also gives the "stated destinations" of those arriving in the State of New York in 1855. He shows, from the 43 destinations quoted, Massachusetts is the seventh most popular. There are also interesting figures of the stated "occupations of emigrants to the U.S.A. in 1852".

.19. Ibid., p.31. Fitch also acknowledges assistance from: Messrs J T Ames, A H Walters, Thomas Warner, James H Burton, Selah Goodrich, the late W W Winchester, General B Franklin, R S Lawerence, Horace Lord, Philos Remington and Eli Whitney.

.20. Jeremy, David J, "Damming the Flood: British Government Efforts to Check the Outflow of Technicians and Machinery, 1780-1843", Business History Review, Vol.51, No.1, Spring 1977, p.2

.21. Ibid., pp.2-5

.22. Op.cit., Gilbert pp.1-5. Also see, M R Smith, Harpers Ferry Armoury and the New Technology, Cornell University Press, (London, 1977), p.245. Smith gives a number of examples of craftsmen plying their trade between different arms-making establishments.

.23. Op.cit., Fitch, p.4

.24. Hounshell, David A, *From the American System of Mass Production 1800-1932*, John Hopkins University Press, (Baltimore & London, 1985), p.38. See also, David Freeman Hawke, *Nuts and Bolts of the Past - A History of American Technology, 1776-1860*, Harper & Row, (New York, 1989), p.107. For details of the Portsmouth block making system, see Carolyn Cooper's article, "The Portsmouth System of Manufacture", *Technology and Culture*, Vol.25, No.2, April 1984. Also, K R Gilbert, "The Portsmouth Blockmaking Machinery", HMSO, (London,1965)

.25. Bedini, Silvio A, *Thomas Jefferson and His Copying Machines*, University Press of Virginia, (Charlottesville, 1984), pp.35-39

.26. Op.cit., *Rees's Cyclopaedia* p.19. For further reading on earlier copying principles, see "Donkin Pantagraph Engraving Machine, with Rose Engine", in *Transactions of the Newcomen Society*: Vol.15, 1934-35, by D M Henshaw.

.27. Op.cit., Hounshell, p.38

.28. Op.cit., Fitch, p.16

.29. Ibid., p.7

.30. *Industrial History of Birmingham and the Midland Hardware District*, Timmins Ed., A Series of Reports, Published by Robert Hardwick, (London 1866), "The Birmingham Gun Trade", John D Goodman pp.418-419

.31. Williamson, Harold F, *Winchester - The Gun That Won The West*, Combat Forces Press, (Washington 1952), p.8 Although Williamson states that Colt established his plant in Hartford 1853, Fitch in the 1882 Census Report quotes 1848. p.8. The confusion is explained when studying David A Hounshell, *From the American System to Mass Production 1800 - 1932*, John Hopkins University Press, (Baltimore & London 1985), pp.46-48. Here it can be seen that Colt moved his machinery from Whitneyville to an empty textile mill in Hartford in 1848. Hounshell gives the date for Colt's *new* factory in Hartford as 1855. However, none of this detracts from the general argument that American industry was not as highly mechanised by the middle of the 19th century as implied by many commentators.

.32. Anderson, John, of Woolwich, *Institute of Mechanical Engineers - Proceedings*, Newcastle 1858, Paper "On Some Applications of the Copying or Transfer Principle in the Production of Wooden Articles", p.238

.33. Ibid., pp.238-243

.34. "The Royal Small-Arm Manufactory, Enfield", The Engineer, Series of articles, March 1859 - June 1859, pp.238-243

.35. Greenwood, Thomas, of Leeds, Institute of Mechanical Engineers - Proceedings, London 1862, Paper "On Machinery for the Manufacture of Gunstocks", p.336

.36. Op.cit., Blackmore, p.118

.37. Public Record Office, Kew.
Gun Stock Making Machine de Barros Ignacio, 1849, Letter from de Barros to R Bayham, 7/8/1849.
Reference WO 44/623/199

.38. House of Lords Record Office, London.
Report of the Committee on the Machinery of the United States of America, Presented to the House of Commons, in Pursuance of their Address of the 10th July, 1855, pp.39-42

.39. Cooper, Carolyn C, "A Whole Battalion of Stockers": Thomas Blanchard's Production Line and Hand Labor at Springfield Armory", The Journal of the Society for Industrial Archeology, Volume 14, No.1, 1988 p.52

.40. Ibid., Letter from B P Pargana to R Byham, 8/8/1849

.41. Ibid.,

.42. Putnam, Tim & Weinbren, Dan, A Short History of the RSAF Enfield, Middlesex University, (Enfield 1992), pp.29-30

.43. Op.cit., Public Record Office, WO 44/623/199

.44. Ibid., Public Record Office, WO 44/623/199

.45. Ibid., Public Record Office, WO 44/623/199

.46. Public Record Office, WO 44/701, Report from R W Hope, Chief Clerk of Stores Accounts Office and Henry Smith, Senior Clerk, Cash Account Office, Tower of London, (8/6/1852)

.47. Ibid.,

.48. Letter in possession of author from Dr Carolyn C Cooper, (14/1/93). Discussing with Edwin A Battison (22/8/94) the issues surrounding the curing of gun stocks, when he ventured the opinion that there was the possibility that the Springfield armoury had used kiln dried wood in the first half of the 19th century. However, subsequent research suggests that this was not the case. According to the Ordnance Department, Washington, Regulations for The Inspection of Small Arms, 1823, p14, "No stocks should be used, which have not been cut from the plank at least three years, and have been stored in a dry place for two years. Kiln dried, or steamed stocks, should not be received." Further support for this directive can be observed later in the century in the article "The Armoury At Springfield", by Jacob Abbott, Harper's New Monthly Magazine, No. XXV1, July, 1852, Vol. V. Under the section entitled "The Stocking Shop", the author states, "The wood used for gun stocks in this country is the black walnut, and as this wood requires to be seasoned some years before it is used, an immense store of it is kept on hand at the Armoury - sufficient in fact for four years consumption". Therefore it would appear that at least between the years 1823 and 1852, kiln dried wood was not used in the manufacture of gun stocks at Springfield.

.49. Op.cit., Rosenberg, America's Wooden Age: Aspects of its Early Technology, pp.54-55

.50. House of Lords Record Office, London. Report of the Committee on the Machinery of the United States of America, Presented to the House of Commons, in Pursuance of their Address of the 10th July, 1855, p.25 (571)

.51. Abbott, Jacob, "The Armory At Springfield", Harper's New Monthly Magazine, No. XXV1 , July, 1852, Vol. V.

.52. Op.cit., Fitch, p.6

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APPRAISING THE EFFECTS OF THE CRIMEAN WAR, "ORDNANCE" FAILINGS, THE TRADE UNION AND PUBLICITY UPON THE ENFIELD FACTORY

The mid 1850s represent one of the most critical periods in the history of British small arms manufacture, one in which apparently unconnected events have together shown remarkable catalytic effects. By focussing attention on this period we are able to identify not only the early changes to manufacturing technology and work-place organisation but also the difficulties experienced by a nationalized industry overseen by incompetent or inexperienced government bureaucrats. Perhaps surprisingly, parallels can be drawn between some of these 19th century events and those which have occurred in the small arms industry of today as the 21st century approaches. A recent example which occurred in the mid 1980s helps to illustrate the point. On this occasion, government bureaucracy interfered with the department responsible for the production of the Enfield SA 80 (Light Support Weapon) and caused confusion amongst the manufacturing staff. The action created a six week production delay, as government officials, who had not properly investigated an isolated complaint of premature weapon discharge, prompted design changes to the gun. .1.

<u>A confused picture</u>

Prior to the expansion of the "Ordnance" factory at Enfield in the mid 1850s, the establishment being the first British manufactory to adopt the technology and principles of mass production by the system of interchangeable parts, the vision of the English gun trade portrayed by research is one of an industry lacking direction and severely stricken by turmoil and confusion. As the middle of the century was reached, the mounting pressure from sections within "Ordnance" for control of the military small arms industry finally took hold, motivated in the main by the requirements of war.

Following the Great Exhibition of 1851, the continuing debate between the private gun trade and the Board of Ordnance over weapon deliveries and quality standards was becoming more acrimonious, the arguments spilling over into the evidence given before the Select Committee on Small Arms in 1854. As we have already discussed, many engineers and entrepreneurs had visited the exhibition held within the Crystal Palace and marvelled at such American exhibits as the Sharpe's rifle manufactured by Robbins & Lawrence and the revolvers of Colonel Colt made with standardized parts. However, there were some established gun makers, like Mr W Scott of Birmingham, who would not entertain the idea that large quantities of machine made products could be accurately produced without the involvement of skilled artisans. When asked by the Select Committee if he thought it possible to produce parts by machines which could "fit into one another perfectly without a great deal of manual labour", he replied "Certainly not; by no means; it is impossible". .2.

Joseph Whitworth's fact finding tour of America in 1853, when he and George Wallis visited a number of diverse manufacturing establishments, and the subsequent visit by the Commission led by Colonel Burn in 1854, which placed substantial contracts for arms production machinery with American manufacturers, were all intertwined with "Ordnance" seeking ways to overcome the problems they were encountering with arms procurement. At the time the

British private gun trade were allegedly falling behind with military deliveries and failing the quality standards set by "Ordnance".

The situation was further complicated by the introduction of the new pattern 1853 Enfield rifle to replace the existing service 1851 Minie and as already argued, there was evidence of "Ordnance" withholding the the new pattern from which the contractors had to copy. Out of this chaotic state there was mounting pressure upon "Ordnance" to equip soldiers in the Crimea with decent serviceable weapons, not only rifles but also swords and bayonets. With the build up of hostilities between Russia and Turkey in 1853 and war between them eventually breaking out in October of that year, it was obvious that a major response would be required from small arms manufacturers. This came when Britain and France entered the conflict in March 1854 after declaring war upon Russia. .3.

Unprepared for battle

During what must be viewed as a critical period in the life of the British small arms industry, correspondence between military regiments and "Ordnance" for the years 1854 to 1855 exposes serious flaws in the "Ordnance" supply chain. These letters indicate quite graphically how fragile the position of Britain really was in arming her troops in time of war. It also illustrates that almost forty years after the establishment of the Government armoury at Enfield Lock in response to the parlous state of the indigenous military small arms industry at the time of the Napoleonic Wars, Britain was still un-prepared for conflict.

The position is clearly illustrated in a letter dated 14th July 1854 from Lieutenant Colonel Griffith commanding Second Dragoons in Manchester to Joseph Wood the Secretary to the Board of Ordnance, complaining, it would seem not unreasonably, about the poor state of his Regiment's weapons. Griffith wrote, "The whole of the Carbines require to be replaced, most of them being worn out from long use. The Victoria Carbines have been mostly in use for 14 years being issued in 1840". Further complaints were made about the "unserviceable" state of the Regiment's swords.

In March 1854 similar criticisms had been raised by the 11th Hussars serving in Ireland. Soon Griffith and his men were to embark for the Crimea without replacement Carbines or swords, 180 new pattern swords finally being issued to the Second Dragoons at their Manchester barrack on 1st August after they had already sailed to the front. When the mistake was eventually realised, the swords were dispatched to the Crimea by the Cleopatra on 11th November. Sadly the error was a costly one, as a communication from the War Department dated 13th December to Joseph Wood, quoted Colonel Griffith as follows:-

> Swords are very defective - as in our engagement, when our men made a thrust with the sword, they all but, and would not go into a mans body, and many of our poor fellows got badly wounded and some lost their lives entirely from the miserable state of their arms. They were quite good enough for home service, but quite unfit for active service. .4.

Unfortunately this was not the end of the Second Dragoon's problems as Colonel Griffith was to write again on the 25th April 1855, reminding Joseph Wood that, before embarkation to the

Crimea, the Adjutant General's letters of 18th and 22nd July 1854 had placed requisitions for carbines and swords. The Board of Ordnance correspondence dated 25th July clearly shows that they had no means of supplying this trivial amount of 286 carbines which Griffith had requested. A note scribbled on the back of Griffith's communication dated 26th April 1855 by an S Roper, states "There is no longer any difficulty in supplying the 286 Victoria Carbines requested by 2nd Dragoons", this was nine months after the original order was placed. .5.

From this episode it is probably fair to conclude that it was Enfield who had responsibility for manufacturing this modest amount of arms, as it was probable that such a small contract would not have been worth putting out to tender. Had this been done, then the delay in suppling the weapons would no doubt have been longer. The competitive nature of the contract system would have required "Ordnance" to distribute and vet the various incoming bids from the private sector and this would have taken time to study and process. Interestingly, this episode also provides a clue to the time required for a factory to adapt to the manufacture of a weapon which was not part of the current production programme. Given the urgency of war, and remembering the weapon was not new and had previously been in production, the incident serves as a general indication of the length of time and the difficulties involved in organising men, mechanisms and material. The introduction of a totally new pattern would no doubt take considerably longer to organise and reach full scale production capacity. New jigs and gauges would have to be made and, of course, machine operators and other personnel would take time to become fully proficient and familiar with the work.

The complaint relating to poor quality swords was investigated by R W Gunner, the Inspector of Small Arms at the Birmingham "Ordnance" office. He reported, "Soon after the introduction of this Pattern in the year 1822 it was found after a careful course of experimental trials that any of the tests beyond those above described was attended with excessive and unnecessary loss either from breakage or failure in elasticity in the fabrication of the blades". .6. Gunner went on to say that the "New Pattern" swords are subject to more stringent tests (Fig.22), the implication being that it was known the military were equipped with inferior weapons and nothing had been done in the forty years of relative peace to rectify the situation. The incident and other reports of poor quality provoked the Master General of Ordnance, Viscount Hardinge, to set up a Committee of Cavalry Officers to look at the current stocks of swords in store and those in the process of manufacture both at Enfield and Birmingham. In addition to the standard tests, Gunner requested the Committee to test the weapons more severely, this they did by "proving the cutting on a bar of iron and the point against a brick wall, without injury in any case to the Swords". After taking evidence from the Inspector of Small Arms and the "Superintendents of the Royal Manufactory", the Committee reported, in January 1855, that, in their opinion, "... the whole of these weapons are made of the best possible materials and they consider them excellent Swords and fit for any service". .7. This statement was made after four of the Enfield swords and one from Birmingham (over two percent of those examined), failed the test. The Committee concluded that in "each instance the fracture was not caused by flaw or softness of metal, but rather from being too highly tempered". .8. While technically the analysis may have been correct, it would be hard to imagine that soldiers in the heat of combat would be interested in the precise nature of the fault. Weapon failure for any reason would have been unacceptable; what soldiers required was reliable weapons in which they could have confidence. Perhaps, at the time, "Ordnance" officers had not appreciated the fact that battles are often won on the factory floor through the quality and quantity of weapons supplied to the troops. The "Ordnance" Committee, detached from the horrors of war, declared on completion of their investigation that the present swords were "fit for any service".

From researching the considerable correspondence on the Crimea, it is clear that soldiers had been sent to the front ill equipped for combat with old issue arms, tragically discovering the inadequacy of their weapons in battle. The failure of the swords in action might indicate that one hundred percent testing and inspection was not being carried out or perhaps some had escaped the view either deliberately or by accident.

Supply and weapon problems

From our discussion it can be seen that there was a whole catalogue of poor organisation, mis-management and incompetence surrounding the procurement and supply of small arms to soldiers on active service. Furthermore, it would appear that there was a complete lack of understanding by members of the Board of

Ordnance relating to the necessary time-scales required by the small arms industry to prepare and schedule the production of new weapons. Apart from senior "Ordnance" personnel in the business of arms procurement having little understanding of how a manufacturing facility operated, it was also apparent that there was a failure to grasp the simple logistics of supplying the troops at the front. The Army in the Crimea had wanted weapons of standard calibre to ease problems in the ammunition supply chain. This would have eliminated the confusion brought about through the issue of more than one size of ammunition. It can readily be deduced from the correspondence between "Ordnance" and the different regiments that at least three types of weapon were in service with the front line troops, all having different calibre bores. .9. Such a mix of weapons of incompatible calibre had introduced severe supply difficulties for the Army. The authorities had tried to resolve these problems on a makeshift basis by keeping batches of the 1851 Minie and Enfield pattern 1853 muskets separate. These were then issued to different regiments. By knowing where the various weapon types were, it was hoped that this would avoid mistakes of wrong ammunition being delivered to the regiments.

With the issue of the new smaller calibre (0.577in.) pattern 1853 it would appear that some of the former strategic advantages of warfare had been lost. For example, Major E G B Reynolds has argued that "It was considered an advantage to have a bore larger than certain Continental armies because, whereas captured ammunition could be fired from English muskets, English leaden balls could not be fired out of theirs". .10.

The 1851 Minie was not the ideal choice of weapon for troops in combat. This can be seen from the many regimental reports which originated from trials carried out in August 1854. Here it was concluded that the barrel of this weapon was too hot to hold after firing between thirty to fifty rounds. Twelve to thirteen minutes had to be allowed for the weapon to cool sufficiently, raising fears that the powder might prematurely explode in the barrel causing injury. Furthermore, the Minie was over one pound heavier than the Enfield pattern 1853, making it less than ideal to carry and handle. .11.

With the many logistical problems confronting the Army, ranging from the supply of equipment to suitability of weapons and ammunition, it would not seem unreasonable to question the competence of the Board of Ordnance and the military authorities. If they were unable to accomplish those tasks which were more suited to their military backgrounds, then it would be difficult to see how they could cope with technical matters concerning the design, manufacturing, and scheduling of weapons.

Shipments of replacement arms from England were slow to arrive at the Crimea, this was primarily due to the problems already highlighted in this thesis, ranging from the contract system and the strictness of view to the failure of "Ordnance" to supply an adequate number of patterns and tools to the private gun trade. By 3rd January 1855, research has shown, there were contracts (not all signed) outstanding for up to 160,000 weapons, mainly the Enfield pattern 1853. Although figures relating to the individual suppliers of weapons are not entirely clear, it can be deduced from the correspondence that orders for 100,000 guns had been placed with Birmingham contractors, 40,000 with Liege, 1,500 with London, and 1000 with Enfield. "Ordnance" had promised that 10,000 of these arms would be delivered to Balaklava by the end of January, with a continuing schedule of 4,000 per month until May and each rifle was to be supplied with 500 cartridges. .12. The grand plan was to have, by August or September, the Army in the Crimea, "entirely armed with rifles of one pattern - that of the 1853". .13.

After all the complaints by "Ordnance" against the private gun trade, the above figures clearly show that they were the only sector of the arms industry capable of supplying reasonable quantities of weapons to the soldiers at the front, albeit behind schedule on occasion, and still by mainly labour intensive methods of manufacture. However, as already pointed out, the delays were not entirely the fault of the private sector. Therefore, the establishment of the "Ordnance" factory at Enfield at the beginning of the century to secure adequate supplies of arms for the military without recourse to the private sector and the necessity of placing orders abroad, had clearly not achieved its goal. The successful lobbying of Parliament by the private gun trade had ensured that Enfield remained incapable of manufacturing large quantities of weapons. This had inadvertently brought foreign imports from Leige into the country when demand for arms increased. Here it might be argued that due to a failure by politicians to fully appreciate the technological requirements of a country with an Empire to police, British interests abroad had been rendered vulnerable by the lack of a strategic weapon manufacturing policy.

Initially, it will be recalled, Government had sought to develop a small arms strategy by setting up Enfield in 1816 but had bowed under political pressure from the private sector. However, we have seen that "Ordnance" had failed to heed George Lovell when he suggested a sensible method of working with the gun trade. No doubt a co-ordinated weapons manufacturing and development programme could have been advantageously cultivated between the private and public sectors based upon Lovell's recommendations. Failure of Government to develop such a scheme in the relatively peaceful period after the Napoleonic conflict left Britain once again vulnerable when war loomed.

Failure of Government to learn from experience

When the British Government decided to send a Commission to America in 1854 to investigate the possible purchase of suitable arms making machinery, the timing almost exactly coincided with Britain's entry into the Crimean War. Even after the Commission had left England, Parliament was still arguing over the amounts of money to be spent on re-equipping the Enfield factory. In fact the initial sum was reduced from £30,000 to the absurd amount of £10,000 but was later reinstated, the Commission being allowed an almost open cheque facility to purchase the necessary machine tools. .14. No doubt the outbreak of the Crimean conflict had persuaded Parliament to release its grip on the purse strings. By the lack of written evidence to the contrary, it would seem reasonable to conclude that "Ordnance" was not working toward a cohesive strategic plan for the British small arms industry with a view to securing future weapon supplies. Therefore, without the pressure created by the Crimean campaign it is unlikely that Enfield would have had the opportunity to become one of the world's leading small arms producers by the middle of the century. The episode would tend to reinforce the notion that the British Government and its advisers lacked a fundamental knowledge of manufacturing matters, particularly an understanding of the planning processes and the time-scales involved in preparing and equipping a small arms production plant. Although it has been shown in earlier chapters that the private gun trade's influence upon Parliament had been exceedingly powerful, by which the trade had successfully resisted "Ordnance" intrusion into their industry, there is no evidence to suggest that Government had the political will or commitment to become involved in full scale small arms manufacture on its own account. Of course it might be argued that the long period of relative peace following the end of the Napoleonic Wars had lulled the British Government into a false sense of security. If this was the case, then it would appear naive in the extreme, particularly if one remembers the vastness of the British Empire and the unpredictability of outbreaks of unrest. Under such circumstances one would have expected Britain to have been vigilant at all times, needing to be positioned to react quickly to restore law and order in any of her overseas possessions. Given such conditions, it would seem rational that Britain would require a plentiful supply of reliable arms to be called upon should such an emergency arise.

Evidence of "Ordnance" ignorance

At a time when there was a desperate need to supply the Army at the Crimea with weapons of standard calibre and type, research at the Public Record Office has uncovered a substantial amount of correspondence between Captain Manly Dixon, Superintendent of the Enfield manufactory and a number of defence agencies relating to mounting pressure to introduce new weapon types. An undated letter from Dixon to "Ordnance" circa 30th May 1855, asked "whether it would be advisable to purchase 1,000 or 1,500 Sharpe's breech loading Carbines instead of issuing contracts for making the Victoria Carbine, a weapon which is all but useless". Dixon went on to suggest that the Sharpe's breech loader is "much superior to anything that has yet been invented" and he further pointed out that the Victoria Carbine "would take 6-7 months to manufacture". This figure would seem rather generous, as it will be recalled that just over a year before it had taken nine months to organise the production of only 286 of these weapons. In a reply from "Ordnance" to Dixon dated 5th June it was stated that Viscount Hardinge has inspected a Sharpe's breech loader and "considers a Carbine invented by Mr Prince to be superior". He also went on to suggest that "some of Prince's pattern be made and distributed for test to the Regiments with the Sharpe's". In the mean-time, Dixon received an order for 4,000 Victoria Carbines to be delivered to General Beatson for the Irregular Turkish Cavalry. Dixon's reply exudes frustration when he states "there are no contracts for material for these arms, at present existing and there are no materials in store". Later in his letter he forcefully concluded "The question now is whether a contract shall issue for an arm for Cavalry purposes which hardly shoots straight at 100 yards, is cumbrous, and difficult to load on horseback and requires a different ammunition to any other arm in the British Army". .15.

This is a damming report by any account and is further evidence of how critical the arms supply situation had become. Not only is it an indication of the plight of the front line troops, but it illustrates the failure of "Ordnance" to recognise or understand the basic requirements of the small arms industry and the time-scales involved in implementing a new manufacturing programme. This latter point should have appeared particularly pertinent to Hardinge, particularly after Dixon had already explained in previous correspondence that the Victoria Carbine, a weapon which had already been in production "would take 6-7 months to manufacture". For Hardinge to propose that an entirely new weapon be manufactured and "distributed for test to the Regiments" would suggest not only that Dixon's former point had been missed or ignored but also that he was prepared to carry out experiments with an untried arm in time of war. This latter fact seems quite extraordinary and almost beyond belief, again emphasising that the military side of "Ordnance" had little idea of time-scales and were seemingly prepared to risk soldier's lives while they were trying to find an improved weapon.

In a further communication between "Ordnance" and Dixon it is suggested that "Viscount Hardinge is now of the opinion that Mr Leitch breech loading Carbine be examined". From the correspondence it would appear that this weapon was being

Leitch, stating "The results showed that in our opinion the arm is less adapted for Cavalry purposes than any other which has been submitted". These views were also supported by Captain Warlow, an experienced "Ordnance" officer and one of the members of the 1854 Commission to America. Warlow found up to six areas of complaint with the weapon. These and Dixon's opinions received the support and backing of James Gunner, Storekeeper at Enfield. A communication to Dixon from "Ordnance" dated 15th August informed him that Hardinge:-

> ... recommends that instructions be immediately given for the preparation of 15,000 of Leitch's breech loading rifled carbines in order that a sufficient reserve at hand to meet casualties. His Lordship would be glad to learn how soon any, and what proportion of these weapons may be expected to be ready in order that the Regiments serving in the Crimea may be supplied at the earliest possible period. .16.

As the date of Hardinge's instruction coincided with that of Dixon's report on the Leitch rifle, is not obvious from the correspondence whether the former communication arrived at Enfield before or after the technical assessment took place. If it came before, this would indicate that the Board had already made up its mind and was therefore not prepared to receive a serious evaluation of the weapon by Enfield personnel. Had it come after, it would imply a large measure of arrogance on behalf of the Board, particularly as the technical advice had come from three of the country's leading experts on military small arms.

Had Enfield not possessed men of the calibre of Dixon and his colleagues who understood not only the intricacies of production and procurement time-scales but military requirements as well, and were also prepared to stand their ground and argue their case with high ranking "Ordnance" officers, it is difficult to recommended for use with the British Cavalry. Dixon therefore suggests as an expedient that Colt's revolvers should be issued to the Cavalry in lieu of the Victoria Carbine. It will be recalled that Dixon had been highly critical of this latter weapon and, apart from it being an old design, there were no stocks available.

In a letter to Dixon from the War Department dated 11th July 1855 it was stated that Hardinge had now "re-considered his opinion and understands that the breech loader would be for the Cavalry only". Dixon was also informed that Hardinge did not want the Sharpe's or Colt's weapons purchased from America and he was given the news that a Leitch breech loader was being sent to him for evaluation after the weapon had already been examined by a Board of Cavalry Officers who apparently found it "excellent practice at 300 yards". This communication was followed by another letter dated 8th August, informing Dixon that Hardinge had "decided the best fire arm for the Cavalry is Leitch's breech loading rifle". The message went on to say "this improved arm will of course do away with the necessity of any more Victoria Carbines being procured". By 15th August Dixon was replying in very strong terms in relation to his findings on the Leitch rifle. Dixon explained that Mr Leitch had been given the opportunity to fire his weapon at Enfield, "a model which he [Leitch] stated had been shewn to the Board of Cavalry Officers and approved by them and subsequently approved and inspected by Viscount Hardinge". The opportunity was taken by Dixon to report on how the rifle performed in the demonstration given by Mr contemplate what fate might have eventually befallen the British soldier. However, the whole episode and particularly the action of ordering Dixon to produce 15,000 Leitch breech loaders, illustrates the Master General's lack of manufacturing knowledge. This clearly demonstrates that Hardinge had no idea of how long it would take to tool-up and prepare for manufacture.

Explanations for "Ordnance" incompetence emerge

It should be recognized that the dialogue between Captain Dixon and in particular Viscount Henry Hardinge has been truncated for brevity. However, analysing the correspondence and noting the critical period during which the exchange took place has provided a fresh insight into behind the scenes actions of senior military and Board of Ordnance personnel. The investigation has helped uncover what is sometimes perceived as the mysteries surrounding certain aspects of military decision making, the results of which are often viewed with incredulity. Those outside the process who question the reasons, which on occasion appear irrational, can begin to understand why certain actions were or were not taken. Historians researching the transfer of the "American system of manufactures" to Britain have failed to fully explore the Board of Ordnance comprehension of military supply chain requirements, particularly at the time of the Crimean War. Now, by opening this line of enquiry it has been possible to demonstrate that certain military and Board of Ordnance officers, with responsibility for supplying small arms to front line troops, lacked a fundamental understanding of the weapon manufacturing process and consequently the ability to appreciate development and delivery time-scales. The correspondence has shown quite clearly that there was considerable antagonism between the technical experts at Enfield, the military and "Ordnance" bureaucrats, further demonstrating that this latter group were not versed in a basic understanding of the problems caused by re-scheduling or re-planning production. Neither had the importance of maintaining long term manufacturing stability through continuity of product design been grasped. It would also appear that the Board had little comprehension of the limitations of the gauges, tools and machinery which had been ordered from America to equip the Enfield factory. This equipment had been specifically designed to support large scale manufacture of one particular weapon, the pattern 1853 rifle, and could not be expected to support any other pattern of arm. Perhaps the problems of a 19th century manufacturing ignorant Government bureaucracy are best summed by G R Searle when he wrote:-

> ...the most important administrative appointments soon became the preserve of "gentlemen" who had benefited from a "liberal" university education, but who possessed neither practical experience nor knowledge relevant to their work. Yet partly because of the assumption that specialists were spendthrifts who needed tight curbing, public officials with technical qualification and attainments usually found themselves subordinated at all points to these "general administrators". .17.

Of course, the lack of understanding by the Board and other military personnel may have been a question of poor communication by engineers but this argument can generally be discounted on the grounds that there had been almost forty years of peace for good liaisons to have developed had there been the will. Views of engineers had been expressed and recorded, some by famous and high profile men like Whitworth, Nasmyth and Anderson, when they drew up reports for Government agencies and gave evidence before the various Select Committees, so it was not as if information concerning engineering and manufacturing matters was unknown in high places. The lack of "Ordnance" understanding can again be seen after the adoption of the Enfield pattern 1853 rifle as the standard arm for the forces in the Crimea. It was hoped that the delivery of this weapon in quantity to the front line troops would overcome the potentially disastrous situation of having more than one type of ammunition in circulation. As pointed out earlier, problems had already been caused for the Army with the issue of a least three different calibre weapons to the front. However, from the correspondence between Dixon and Hardinge it can be seen that the Board and influential military officers were changing their minds almost daily, encouraging Enfield to introduce new weapon types, some of which, if accepted, would require additional designs of ammunition and training of the men, hardly a situation to be contemplated when war was raging. While these distracting communications between "Ordnance" and Enfield were taking place, it should be remembered that substantial contracts had been placed with the private sector for the pattern 1853 and shipments of the weapon to the Army were already underway.

Investigating the correspondence between "Ordnance" and Enfield has helped to clarify the reasons governing the timing of the British Government's intervention into the traditional small arms manufacturing business of the private sector, bringing about for the first time the entry of "Ordnance" into large scale military weapon manufacture. In fact it is the clarification of the timing issue which has provided important information, showing how Enfield was catapulted into adopting revolutionary methods of mass production with new imported machine tools, rather than having a more sedate and evolutionary approach to large scale arms manufacture. Had the Crimean conflict not come about, then Enfield may well have retained its original role as a small scale manufacturing unit with responsibilities for weapon repair, research and development.

Playing a dangerous game?

Early in 1855 work on the new buildings began at Enfield to house the machinery on order from America, the task of construction being undertaken by the Royal Engineers under the command of Major General Collinson. .18. While preparation for the site's expansion was taking place a decision to alter dramatically the terms and conditions of the workforce was implemented. A memorandum dated 4th July 1855 explained that the current terms and conditions of workmen employed by the "Ordnance" establishment at Enfield would be suspended as of the 21st "when they will be considered as ceasing to belong to the factory - as it is hoped that many will be willing to re-engage under the new system". The new arrangements required "...old hands to be pensioned", and it was proposed that workmen "...such as receive it [pension] for long and faithful services shall be recommended for a gratuity". Furthermore, an abstract of the rules was to be hung in the factory telling the work-force that they would have to apply to the Superintendent before the 17th July to be re-engaged. The working hours were to be brought in to line with other private factories in Britain, 10.5 hours per day for the first five days and 7 hours on the sixth, bringing the total working week to 59.5 hours. Even senior craftsmen did not escape the changes. All Superintendent Armourers were informed that, on the 23rd of July, they would receive their instructions from the Tower "under the immediate superintendence of Mr Phillcox but subject to the order and charge of Mr Turner". Time keeping was to be formally structured, gates to be opened at 5.45am, work commencing at 6am, workmen arriving 5 minutes late would be deducted 15 minutes pay, arrival after 6.15am would see 30 minutes pay deducted. Gates were to be closed at 6.30am, workmen arriving after this time would have to wait until the breakfast break at 9am to be allowed in. There was to be a time book which would show the punctuality or lateness of the employees and this would reflect the amount of wages received by individuals. Wages would be paid before the Saturday dinner break. .19.

From the timing of the new working practices it would seem that management had taken a terrible risk. The act of introducing these fresh terms and conditions could have easily provoked a serious strike. With Britain deeply involved in the Crimean War, further problems with the supply of arms would seem to have been the last thing Government wanted. It was probable, however, that "Ordnance" felt confident in taking this action, perhaps banking on the knowledge that memories of the 1852 "great lock out" were still fresh in workers minds. The risk of industrial action may also have appeared slight, because, as the Enfield factory was a Government establishment, the workers enjoyed better terms and conditions than their private sector counterparts. From the rapidly rising output of the Enfield factory after January 1857, it would seem fair to conclude that the changes went through relatively smoothly.

Birth of the Union

With the organizational changes taking place, it is probably no coincidence that on the 5th November 1855 the Amalgamated Society of Engineers (ASE) formed the Enfield Lock Branch. The inaugural meeting was attended by the Union's General Secretary, William Allan, who formally declared the Branch open. Unfortunately the Union minute books for this important period in the birth of the Branch are incomplete and the early entries are erratic. For example, the second entry does not occur until 24th February 1857, the business being conducted is of a general administrative nature and sadly does not refer to the introduction of the new American machine tools at the Enfield factory.

From an examination of later entries in the minute books, it can clearly be established that the Branch was catering strictly for skilled craftsmen only. This applied not only to members serving the necessary time appropriate to their trade but also to discrimination against men with physical disabilities. Membership of able bodied men was actively encouraged as this was thought necessary to maintaining high standards of craftsmanship. At the time, skilled worker's jobs were under threat from the increasing number of machine tools being introduced into the Enfield factory. The following examples taken from the minutes give a clear indication of the measure of strictness being operated by the Branch in an effort to preserve and maintain a skilled membership:-

> October 26th 1872 - That the sympathy of this Branch be conveyed to Mr Tuckey on his being disqualified to becoming a member of this Society through his loss of two fingers on one hand.
>
> January 17th 1874 - That Thomas Tanner be admitted a member of this Society. He having undergone an examination by Doctor J Hutchinson of the Ophthalmic Hospital, London, who certifies that his left eye is perfect, and that the right eye suffers from a congenital defect and that it will not be detrimental to his following his employment.
>
> January 31st 1874 - That our Secretary be instructed to write to the Council to know whether we are justified in admitting a member suffering from a rupture to the sick benefit of our Society.
>
> October 10th 1874 - That our Secretary be requested to write to Newcastle informing the Secretary that James Trigg was not working at this Factory as a mechanic he being employed while working here on the component parts of the gun. .20.

On reading these extracts one is left with the impression that a type of craft elitism was being operated. This may have accounted for the relatively small number of men belonging to the Branch. In 1855 the Branch membership was only forty four, rising to one hundred and twenty two by 1880. .21. The work-force estimates of the RSAF Superintendent and historian G H Roberts, suggest that in 1858 "... about 1,000 unskilled or semi-skilled and 250 men were employed, a considerable number of whom had come from Col. S. Colt's Factory at Pimlico". .22. Therefore, during the early years of the Branch, membership as a proportion of workers employed at the factory was less than 4%.

A climate of mixed views and uncertainty

After almost forty years of only partial manufacturing involvement, Government had been forced by war to accept responsibility for the full scale production of military small arms. However, the plan to expand Enfield was not shared by all politicians, some taking the view that a Government owned armoury was not essential, believing that the private gun trade could provide all of Britain's military requirements without placing an undue burden on the Exchequer. Research has shown that, if "Ordnance" had sought to establish sensible long term contracts with the private sector and taken the trouble to foster good relationships with the gun makers, supplying them with reasonable quantities of patterns and gauges, a reliable source of military weapons could have been developed with minimum reliance upon public expenditure.

The report of the Select Committee on Small Arms 1854 was able to present an objective analysis of the problems befalling the gun trade in the supply and manufacture of military weapons. In drawing up their report the Committee reached the following conclusions:-

> While Your Committee recommended the system of contracting for the supply of Small Arms should not be discontinued, they are, nevertheless, of opinion that a manufactory of Small Arms under the Board of Ordnance should be tried to a limited extent. This manufactory would serve as an experiment of the advantages to be derived from the more extensive application of machinery, as a check upon the price of contractors, and as a resource in times of emergency, and it should be arranged with a view to its economical working. .23.

While it is clear that the Committee wanted to retain the contract system and had not wished to give Enfield sole responsibility for the production of all military small arms, their recommendation had nevertheless allowed "Ordnance" the opportunity to keep their feet firmly in the manufacturing door.

When Britain joined the conflict in the Crimea, followed by the purchase of machine tools from America, the chance for "Ordnance" to push the door fully open finally came.

It would seem unreasonable to assume that politicians were unaware of the high levels of expenditure required to fund a fully mechanised modern small arms factory on a continuous basis. Apart from the financial information coming before the various Select Committees, there was also the examples of factories directly under "Ordnance" control, like Woolwich Arsenal and Waltham Abbey Gunpowder Mills. Furthermore, from the haphazard and intermittent working of the contract system, it should have been obvious to politicians that there were no individual manufacturers outside of Government who were big enough to have the confidence, let alone the finances, to risk investment in a large scale manufacturing plant. Many private companies had yet to be convinced of the superiority of the "American system of manufactures" over the traditional labour intensive methods of gun production. This latter system had generally served them well over the years, allowing the private sector the flexibility to exploit different markets at minimum capital outlay.

Politics slow engineering influence

It was not only politicians who had appeared to lack the imagination and understanding of the needs of their armed forces at a time of a rapidly changing technology, after all many were under pressure from their gun making constituents. The collective responsibility of the Board of Ordnance was also found wanting. They had allowed the British Army to embark for the Crimea with inadequate and out of date weapons. Moreover, as research has shown, even the Master General was prepared to continue a time consuming and unhelpful dialogue with the technical and manufacturing experts over the introduction and trial of new weapons. This not only demonstrates a lack of understanding of the planning required in the manufacturing process but also an ignorance of the problems which would have undoubtedly been caused by issuing unfamiliar weapons to soldiers at the front (or perhaps it was naivety). Placing untried battlefield weapons in the hands of men in action, who had not been give the opportunity to train with them, would have no doubt resulted in disastrous consequences, not to mention confusion if new types of ammunition had to be issued as well.

The lack of "Ordnance" understanding of manufacturing issues would suggest that by the middle of the nineteenth century the voices of the engineers and technicians, although beginning to gain respect, had yet to be allowed to influence the decision making process. Perhaps Viscount Hardinge was still stirred by his earlier experiences of the former Inspector of Small Arms, George Lovell, as he had expressed the view, although possibly unfairly, that "The Inspector has an undue confidence in his own authority to act independent of the Board or of my own authority ...".24.

The timing of the expansion and equipping of the Enfield factory when the Crimean War was in progress demonstrates clearly how unprepared the Board of Ordnance were for major conflict. In fact the situation is even worse than it appears on the surface. A report, called for by John Anderson, Inspector of Machinery and published in 1857, suggests that the new factory to house the machinery from America was originally planned for Woolwich. It was not until 2nd February 1855 (after Anderson's return from the United States) that the Board of Ordnance gave the order to commence building on the Enfield site. Naturally this caused further delays as plans had to be redrawn and the work put out to tender. The building was completed in 1856 but not before more costly delays were encountered due to "... the ground being a bog of peat...". .25.

As it has been shown, the whole episode surrounding Government small arms production in the early to mid 1850s is one of general indecision, confusion and "Ordnance" incompetence. This would seem to be an extremely serious state of affairs for the British nation to be placed in, particularly when considering the developing international scene. It was not as if politicians had suddenly realised that if Russia was to occupy Turkey, then India, the jewel in the British crown, would suddenly become exceedingly vulnerable. Russia had been expanding her Empire for years and there was more than enough intelligence information from British agents to have caused politicians considerable anxiety. .26. More than ever, the British Government needed an arms manufacturing strategy which would introduce stability to the supply of weapons to her troops. Would the incoming "American system", developed by engineers, based on new production and assembly principles, achieve this?

Time for change

The arrival of the "American system of manufactures" (as it later became known) in Britain was to show, by the early 1860s, that Enfield was in a position to influence dramatically and change totally the method of British small arms production. At the time it was probably not fully appreciated how this new system of manufacture might affect other industries in Britain. The change appears to have been influential on at least two levels. First, the publicity given to Enfield had made the factory highly visible. This had set other industrialists thinking and they began considering the installation of new plant and equipment. Secondly, the new factory processes had imposed different standards on contractors which by the 1860s meant external supplies of military arms would only be accepted by "Ordnance" if made with interchangeable parts. This caused suppliers like the London Gun Company and the amalgamation of Birmingham gun makers (by 1861 called BSA) to implement machine intensive production.

Although not referring directly to Enfield, Clive Treblicock wrote in relation to his "spin-off" theory, "The intricacy of the new weapons, the excellence of the manufacturing equipment, the heavy commitment to research - as well as the advocacy of the trade journal - would strongly suggest that by the 1880s the British armament industry had reached a level of technical achievement from which it could profitably influence "civilian" industries". .27. Free of pressure from the private gun trade and without the need to play political games with the contractors, Enfield's role had changed from a small volume repair shop to that of a major international small arms manufacturer. By 1860 the annual production figure for rifles alone had reached 90,707 - 1744 per week. .28.

Enfield's growing fame

A visible consequence of the Enfield factory, after full-scale production commenced in January 1857 with the imported American machine tools, was the vast amount of attention it attracted, particularly from the national press. Articles appeared in newspapers and learned journals proclaiming admiration for the manufacturing system and extolling the "beauty" of the machinery installed at the plant. The reporting in some instances exuded such national pride that the reader might be forgiven for believing mistakenly that the factory and its equipment was a marvellous piece of solely British ingenuity. Being cynical, it could be argued that this was the Government encouraging publicity for the factory as a way of justifying to the public the large amount of capital expenditure, rather than simply being a piece of Victorian pride.

In the period immediately following the cessation of hostilities in the Crimea much publicity was given to the new factory highlighting its modern production techniques and machine tools. Although several articles paid tribute to American machine manufacturers Robbins & Lawrence and the Ames Company, the references were often glossed over as in the case of The Mechanic's Magazine of 23rd August 1861. The machinery designers are referred to as "our American cousins", implying that the writer was trying to claim credit for Britain through a family connection. .29. The fame of the Enfield factory was not short lived, neither were the admirers confined to the world of adults. No doubt wishing to encourage the younger generation and perhaps to secure the craftsmen of the future, the Boys Own Magazine ran an article in 1860 entitled "Manly Exercises, Rifles and Rifle Shooting" which gave an account of weapon manufacture at Enfield. The writer, obviously overwhelmed by the experience of his visit to the factory, described the large machine room in the following florid terms:-

> Let our readers imagine, if they can, a single room more than an acre in extent, lofty, and well lit, in which some thousand men and boys are increasingly employed in superintending machinery. The ear is pained by the hum of fly-wheels, which revolve in thousands till the eye is giddy with their whirl. Miles of shafting are spinning round mistily, with a monotonous hum; the room is almost darkened, and the view completely obscured, by some 50,000 or 60,000 feet of broad, flapping lathe-bands, which are driving no less than 600 distinct machines, all going together, on their own allotted tasks, with a tremulous rapidity and ease that seems to swallow up the work like magic, and the first sight of which is inexpressibly astonishing to the spectator. It takes some minutes before the visitor can subdue the over-whelming feeling of surprise which this scene of activity always excites, no matter how often entered on. .30.

John Anderson, the engineer from Woolwich Arsenal who had been a member of the 1854 three man Commission to America, gave lectures to the Institute of Mechanical Engineers. In 1858 he read a paper in Newcastle on the applications of the "Copying or Transfer Principle in the Production of Wooden Articles" in which he described the sequenced operation of the new gun stock forming machinery at Enfield. A further paper in 1862 on the "Copying Principle in the Manufacture and Rifling of Guns" was given in Birmingham. Here Anderson described the levels of precision attained in machining and measurement at the Government ordnance factories at Woolwich and Enfield. At the end of the lecture the chairman remarked that members would have an opportunity to visit "... the works at Woolwich and seeing the whole of the processes described in the paper in the manufacture and rifling of guns; and also of visiting the Small Arms Factory at Enfield, where the same principles had been carried out by Mr. Anderson, and the same accuracy of workmanship attained". .31. While Enfield was enjoying the attention and prestige of a modern state of the art factory, there were remarks from members of Anderson's audience which suggested that Britain's manufacturing industries were suffering from under-investment. A Mr. Richardson, who had previously visited the Woolwich factory, commented "It would be a great advantage if the engineering workshops throughout the country would endeavour to approach to the same amount of perfection, by employing a better class of machinery and tools, which would produce an important advance in mechanical engineering". .32.

The increased productivity brought about by the introduction of the new machine tools coupled with the technology of interchangeability, gave Enfield a reputation as a centre of excellence. This point was emphasised by Howard Blackmore when he quoted William Greener the respected quality gun-maker, a man apparently not given to generous comment, although he said of the factory "Enfield, the seat of the Government manufacture of small arms, will become a celebrated place in future history; its productions being now one of the wonders of the present age". .33. Greener's view supports the notion that Enfield was seen more in terms of making a contribution towards production technology rather than having a role as a small arms design centre (aspects concerning weapon design will be discussed in Chapter Ten). Here it will be shown that a system of open competition, where private inventors were invited to submit their designs, was being operated by "Ordnance". The role of Enfield was more of a trial judge and weapon modifier rather than a design house.

The message spreads to the private sector

With the repeated enthusiastic coverage given to the Enfield factory by journalists and others, and the influencing of engineers and entrepreneurs through lectures within learned societies, the conditions were building up for a watershed within the British gun trade. Continually suffering shortages of skilled labour, yet encouraged by the sudden demand for arms brought about by the outbreak of war in the Crimea and later by the American Civil War in 1861, it had become clear to the private gun trade that if it wished to secure future orders for military weapons, manufacturing methods within its industry would have to change dramatically. No longer could the private sector expect to enjoy the same monopolistic conditions which prevailed prior to 1854 and which had effectively denied "Ordnance" the ability to compete for military small arms contracts. Now the private gun trade would have to compete with the much publicised and highly visible Government factory at Enfield which was now able to dictate even stricter terms on which "Ordnance" would accept weapons and parts. In future, weapons would only be accepted if they conformed to a precise standard and were manufactured with interchangeable parts. .34. For generations the private gunsmiths had operated within a system of small shops employing mainly hand skills. If the private industry was to survive late into the nineteenth century and beyond, it would need to alter dramatically its method of production. The gauntlet had been thrown down by Enfield and the private gun trade was about to pick it up and accept the challenge by altering its method of manufacturing military weapons.

In 1861, four years after the RSAF commenced full scale production with the imported machinery using the techniques of interchangeability, a group of midland firms came together to erect a new small arms factory at Small Heath in Birmingham. The plant was similar to the installation at Enfield and purpose built, modelling itself on the "American system" using the techniques of interchangeable production. Over the coming years, the conglomerate known as the Birmingham Small Arms Company (BSA) would demonstrate how the lessons learned from the manufacture of standardised weapons could be transferred to the mass production of consumer products such as the bicycle.

Perhaps the most significant change for the private sector came from a complete reversal of Government policy which moved from a position of obstruction and arms length dealing to one of close cooperation. Instead of withholding patterns and gauges as they had in the past, Enfield was actively encouraged to assist BSA in making weapons which were compatible with their own production and therefore interchangeable between factories. The following statement by a grateful Birmingham Small Arms Company shows just how far "Ordnance" had moved from its earlier position:-

> Every assistance has been rendered to the directors by the War Dept. of H.M. Government. The experience of Enfield has been freely placed at their disposal; free access has been granted to the Royal Manufactory with permission to make drawings of machinery. Models and gauges have been supplied which have effected for the company an incalculable saving. .35.

This was a far cry from the denial of the means of measurement which had occurred during Lovell's time as Inspector of Small Arms.

Government encourages industrial investment

Although it is true that BSA took delivery of specialist gun stocking machines from the Ames Manufacturing Company of Chicopee, Massachusetts similar to those supplied to Enfield, the pattern of machine tool acquisition was beginning to change. Roger Lumley has concluded from his research that claims suggesting the majority of the early machinery installed at BSA had come from the United States of America were false. During the 1860s, out of a total of 430 machine tools purchased, only 65 came from the U.S.A., the original order for American equipment being cancelled at the outbreak of the Civil War of 1861. Of the 2,324 machines purchased by BSA in the 19th century, less than 7% came from abroad. .36. The Leeds based company Greenwood and Batley, which was only founded in 1856, were rapidly becoming recognized both at home and abroad as a quality producer of machine tools for the manufacture of small arms. Prior to supplying BSA this manufacturer had already equipped the London Armoury Company, giving it an output capacity capable of reaching 900 complete arms per week. .37. So in a way the machine tool story relating to self acting mass production methods had come full circle. The ideas transferring to America from Portsmouth and elsewhere at the beginning of the century, returning to Enfield by the middle at an advanced state of development to be taken up by British machine tool manufacturers, who spread the technology within Britain and abroad. Ironically and by default, the British Government, by its ability to place large orders for small arms, had broken the mould of the private sector's small workshop culture, forcing investment in capital equipment through the formation of larger manufacturing units. Looking from the position of the 20th century, it can be seen that the act of importing specialised machine tools from America was an extremely influential component in a cocktail of many ingredients which helped to shape British light engineering. Although the introduction of the machine tool into the small arms industry influenced the spread of mass production technology in Britain which eventually transferred to other industries and encouraged greater size, it also had the effect of reducing the ability of industry to be flexible, thereby limiting the individuality of the product. Therefore, standardisation of parts became to mean standardisation of product.

NOTES

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The article gives a classic illustration of how confusion between a government manufacturing plant (RSAF) and a government body (MOD), over the alleged accidental firing of the SA80 when dropped, caused production delays by bureaucrats insisting on modifications to the weapon which were probably unnecessary.

.2. House of Lords Record Office, London.
Report from the Select Committee on Small Arms, 12th May 1854, Reports Committee's Vol. XV111-1854, P.257

.3. Holt, Elizabeth, The Crimean War, Wayland Publishers, London, 1974, pp.117-119

.4. Public Record Office, Kew.
Correspondence between Lt. Colonel Griffiths, Mr J Wood, Ordnance and War Department, 1854 -1855.
Reference WO 44/701. It is worth noting, that from the closeness of the dates on this correspondence, that is to say, sent 25th April, note on back 26th April, suggest that the message had been telegraphed. As a point of information, there was in fact considerable telegraph activity at the Crimea. The Gateshead firm of Newell & Company took part in laying a marine cable under the Bosphorus and the French had established a link to Paris. This therefore corrects the statement of the American Historian, F W Foster Gleason, when he suggested that the Civil War of 1861 was the "first telegraph war".
Public Record Office, Kew.
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Gleason, F W Foster, "Arms For Men", Ordnance, July/August 1961, pp.62

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.12. Public Record Office, Kew.
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.14. House of Lords Record Office, London.
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.15. Public Record Office, Kew.
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.16. Ibid., WO 44/701

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Roberts, G H, CBE M.INST. C.E. (Superintendent RSAF 1922-1931), "Notes on The History Of The Royal Small Arms Factory, Enfield Lock". Unsigned typed manuscript c1931, p.C10

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.20. AUEW District Office, Edmonton, London.
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See also, The First 80 Years, Some Account To 1935 of the Enfield Lock Branch (founded 1855) of the Amalgamated Union Of Engineers and Foundry Workers, Formerly the A.E.U. Originally the A.S.E. p.4

.22. Op.cit., Roberts, p.C11

.23. House of Lords Record Office, London.
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.24. Bailey, De Witt, "George Lovell And The Growth Of The RSAF Enfield", Paper presented at MA Day School, Middlesex University, 4th July 1992, pp.8

.25. Public Record Office, Kew.
WO44/701. *General Statement of the Past and Present Condition of the Several Manufacturing Branches of the War Department, as called for by a letter dated 8th may 1856 by John Anderson, Inspector of Machinery*.

.26. Richards, D S, *The Savage Frontier, A history of the Anglo-Afgan Wars*, Macmillan, (London, 1990), pp.1-16

.27. Treblicock, Clive, "Spin-Off In British Economic History: Armaments and Industry 1760-1914", *Economic History Review*, 2nd Ser. XX11, 1969, pp.481

.28. Op.cit., Roberts, p.C12

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.31. Anderson, John, " On The Application Of The Copying Principle In The Manufacture And Rifling Of Guns", Paper given before *The Institute Of Mechanical Engineers* Proceedings 1862. Published by the Institution - Birmingham 1862, pp.125-145

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.34. Lumley, Roger, "The American System of Manufacturers in Birmingham: Production Methods at the Birmingham Small Arms Co. in the Nineteenth Century", *Business History*, Vol.31, 1989 p.37

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THE QUEST TO EQUIP ENFIELD AND INTERCHANGEABILITY RE-EXAMINED

The debate surrounding the technology of interchangeable parts has occupied the minds of engineers for over two hundred years. Latterly research has been undertaken by historians concerned with both the economic and technological evolution of the subject. According to Joseph Wickham Roe the system of interchangeability originated in France in the eighteenth century. .1. Howard Blackmore has produced evidence to suggest that a crude form of producing carbines or fusils in England to conform in "every way as good as ye Patterne" originated in the seventeenth century. .2. Whatever the truth of its origins, it is probably fair to say that the "American system of manufactures", as the process was to become known, developed from the ideas of many individuals and was improved and enhanced by later generations of technicians and engineers. The story of how the system came to Britain from America (perhaps arguably returned to Britain) in the middle of the nineteenth century helps to illuminate aspects of early machine tool development. Investigation of this particular branch of technology will allow a picture to emerge of the relationship between government, private industry and the individual weapon and machine tool designers. The study will show that these relationships exhibited quite different characteristics within the military small arms sector on either side of the Atlantic. Discovering how these associations functioned can help further our knowledge of why the British small arms industry developed in the way it did.

Fact finding in America

As we have discovered in the last chapter there had been growing reports circulating within 19th century Britain that high levels of mechanisation were being employed by American manufacturers. First hand evidence of this had been gathered by Joseph Whitworth, the eminent engineer, when he visited the New York Industrial Exhibition of 1853 and subsequently the Government arms factory at Springfield, Massachusetts. Whitworth had been particularly impressed by the system employed in the manufacture of gun-stocks, reporting that "this operation was performed entirely by machinery, with the exception of some polishing with sand-paper, a labour which was performed by hand, but did not occupy more time than two minutes". .3.

Pressures were beginning to build for the Board of Ordnance and there was an increasing urgency to investigate the advantages of using higher levels of machinery within the small arms industry. In 1854 the Board responded with two initiatives. First, it created a Committee on the Machinery of the United States of America to investigate new procedures and procure American equipment. Secondly, it initiated a Select Committee on Small Arms to investigate the more general aspects of the alleged failings of the gun trade and to study how best to procure a continued supply of reliable weapons. As British involvement in the Crimean War approached, this latter initiative was becoming more urgent by the day.

In February, the Board of Ordnance produced a Minute which directed Lieutenant Colonel Burn, Royal Artillery, Assistant

Inspector of Artillery, Woolwich "to proceed to the United States of America on the 18th instant, for the purpose of inspecting different gun factories in that country, and purchasing such machinery and models as may be necessary for the proposed gun factory at Enfield". The Board's Minute also directed Lieut. Col. Burn to "put himself in communication with Mr Whitworth, and ascertain from him the name and residence of the principal makers of machinery in the United States, and the gun factories, whether in the hands of the Government or of private individuals". The communication was sent by the Secretary of Ordnance on the 13th of February (the same date as the Minute) on behalf of the Board and Master General, giving Burn instructions to travel to the United States of America "and act as therein directed". The Secretary further informed Burn that "I am to add that Lieut. Warlow R.A. and Mr Anderson [Ordnance Inspector of Machinery] have been instructed to proceed thither on the 4th March and to place themselves under your direction, and I request that you give them such instructions previous to departure as you may consider necessary". Before leaving England, Burn took the opportunity to seek the advice of Colonel Colt, the prominent American small arms manufacturer, who had set up a pistol factory in London after the Great Exhibition of 1851. .4.

On 25th February Burn left for America, arrived in Boston on 10th March and proceeded to Washington to gain permission to visit the various armouries and arsenals. His tour, however, was delayed for several weeks as he awaited his colleagues, Warlow and Anderson, who did not arrive until 26th April, being held back to participate in the Board's second initiative that Spring. The three took the following day to decide their route which was to include some fifteen towns and cities, taking in almost sixty different places of interest and sites of manufacture. These included such diverse product areas as felt hat making, biscuit manufacture, stone cutting, india-rubber shoe making and many different arsenals, along with a collection of gun makers and machinery manufacturers. .5. It is clear, from the list of places visited, that the Committee wanted not only to see how machinery was employed in America in the production of small arms but also wished to obtain an understanding of how extensively machines were used in other branches of industry.

The Committee's task frustrated

Initially, the Treasury had approved the sum of £30,000 to allow the Committee to buy the machinery which they considered best to equip the Enfield factory. When the "Ordnance" estimates were brought before the House of Commons by Mr Monsell, M.P., Clerk of the "Ordnance", the motion calling for £150,000 to build a Small Arms Factory was opposed on the grounds that the London and Birmingham gun trade were perfectly capable of supplying "Ordnance" with all their needs at a lower price than a government manufactory. The decision not to grant the capital sum probably suggests that the continuing lobbying of Parliament by the private gun trade was still powerful and effective.

Warlow and Anderson had been deliberately held back from their visit to America, primarily to allow the Select Committee on Small Arms to have the benefit of their knowledge and expertise.

When they eventually embarked for the United States on the 15th of April, it was in the knowledge that the sum they could spend on machinery and equipment had been drastically cut from £30,000 to £10,000. .6. There is no doubt that this reduction had considerably complicated the Committee's task of placing orders for sufficient quantities of tools and machinery to equip the Enfield factory. For example, on 17th May the Committee had agreed to accept a tender from James T Ames for 30,860 dollars to supply gun stocking machinery. .7. On 25th May, while in New York, the Committee received a quotation of 22,665 dollars from Robbins & Lawrence to supply machinery to produce the lock, heel plate and trigger guard for the Enfield pattern 1853 musket. Due to the limitations on expenditure, the quotation was reduced to 17,515 dollars by leaving out a number of essential tools. Burn was then forced to write to the Master General of Ordnance on 25th May, requesting that the amount of expenditure be increased to £12,500. With the larger sum, he argued:-

> ... they could not only accept the tender of Messrs. Robbins and Lawrence for the whole plant of machines, but also, by getting duplicates of two, and triplicate of one of the sixteen stocking machines (making in the whole twenty), the produce would be trebled, on account of the difference of time taken by the different machines in completing their portion of the work, so that instead of sixteen machines producing, say, fifty stocks per diem, the addition of only four would increase the number turned out to 150 daily. .8.

According to the official report from the Committee, as listed in their "Report of the Committee On The Machinery of the United States of America", while in Washington Burn received a reply from J Wood the Secretary to "Ordnance" dated 14th June 1854. Wood's letter contained the following information; "Having submitted to the Board your letter of the 25th ultimo, requesting authority for the provision of Small-Arms Machinery in the United States, I have their commands to inform you that you are authorized to make any purchases you may consider to be desirable". .9. However, research at the Public Record Office, Kew has shown that prior to receiving Burn's letter the decision had already been taken in England to allow the Committee greater flexibility to purchase machinery. In a letter dated 26th May, Mr Monsell M.P. sent Colonel Burn a note from Sir C Trevelyan of the Treasury. Trevelyan's note, suggested Monsell, "contains the true principle" and made the task of the Committee quite clear, even emphasizing it with underlining:-

> I think that the instruction to Mr Anderson and his colleagues should be <u>to bring back with them a specimen or model of every machine used in America in making musquets the introduction of which into this country is likely to be attained with advantage</u> - Nothing short of this would meet the case. .10.

A further letter was sent to Colonel Burn from the Office of "Ordnance" on 31st May giving him authorization to engage Mr James Burton (late of Harper's Ferry Armoury) as Superintendent Assistant Engineer, to supervise the installation of machinery purchased in the United States. .11.

While the two aforementioned letters were obviously good news, at first glance it seems incredible that in the mid-1850s, almost half a century after the case was first made to establish Enfield as the catalyst for improving the capabilities of the British gun trade in order to produce adequate quantities of small arms to equip its army and navy, the arguments were still raging at Government level over the need for the industry to modernise and the amount of money to be spent. Furthermore, it would appear particularly curious if one takes into account the fact that, in

March 1854, England and France had entered the war in the Crimea which had already been raging for almost six months. One might be forgiven for adopting the view that the British Government had not learned from its previous mistakes but the incident would seem to be an indication of the continuing strength of the lobby by the private gun trade upon Parliament. So history was to repeat itself once more, as "Ordnance" was forced to rely on foreign imports of small arms from both Europe and America to supplement supplies from the British private sector in order to equip its hard pressed front line troops.

Impressive machine tools and scarce designers?

There is no doubt the Committee were suitably impressed with the machinery they had seen in use for the manufacture of small arms during their months in the United States. They were highly complimentary of the Sharpe's Rifle Company at Hartford, a subsidiary of the machine manufacturers Robbins & Lawrence. At the National Armoury at Springfield, they became most enthusiastic with regard to the sequenced operation of the Ames wood-working machinery used in the production of gun stocks. To test the machinery to the full, the Committee arranged with Colonel Ripley, Superintendent at the armoury, to have some English walnut stocks, which were harder than their American black walnut counterparts, put through the shaping process. Although the stocks were not completely dry owing to moisture absorbed during the sea crossing from England, Burn and his associates were delighted with the results. As a further example of the Committee's thoroughness, it is interesting to read in their report that they did not immediately approach the Ames company for a quotation but spent some days at the factory observing the wood-working machines in operation and examining other processes.

When the Committee finally requested a quotation from the Ames company, they were informed by Mr Ames that unless he "could be assured of the co-operation and assistance of Mr Buckland, Engineer to the United States Armoury, in designing the "stocking" machines he could not undertake to make them at all". Colonel Ripley sanctioned his engineer's involvement and the Committee arranged that Mr Buckland would receive one thousand dollars for his services upon successful completion and delivery of the machinery. .12. This arrangement had several remarkable aspects. That the American National Armoury was prepared to be so co-operative and that the engineer concerned was to receive a fee for his services while still working for the United States Government not only raises questions about the relationship between government and private industry but suggests an opposite approach to that which was currently in operation in England. Research has shown that under the "Ordnance" contract system, there is little evidence which would indicate a good working relationship between the public and private sectors (these issues have already been debated in Chapter's Five and Six of this thesis). It will be recalled that the Board of Ordnance had operated a strict arms length policy with its contractors and had warned its former Inspector of Small Arms, George Lovell, not to get involved when he tried to improve the working relationship between "Ordnance" and the private sector in the 1840s.

Questions regarding the possible scarcity of skilled engineers are also raised by the refusal of the Ames company to tender for the machines without the services of Cyrus Buckland, an employee of the U.S. Government. This might suggest that machine tool design engineering skills were rarer than commonly believed in America during the middle of the nineteenth century and it could also indicate that machine manufacturing companies did not generally wish to carry the cost of employing full time design engineers. This reluctance would explain why such a talented engineer as Buckland was working for the Government National Armoury, rather than a private machine tool manufacturer, where, it would seem, his particular skills would have been more appropriate. Could it be that American machine tool manufacturers had not yet begun to convince the indigenous manufacturing community of the necessity to mechanise their production? In his report of 1882, Charles H Fitch suggests that this may, indeed, have been the case. "Apart from all consideration of the earliest usage of specific machines," he reports, "it must be said that their introduction did not make itself felt as a great industrial agency until within twenty-five years past...". According to Fitch, the great increase in mechanisation in the United States did not occur until around 1857, some three years after the visit of the British Committee on Machinery. .13.

Of course, Buckland's reasons for working at Springfield may have been a simple matter of being able to obtain better terms and conditions at a government establishment. However, at this stage one can only speculate on Buckland's reasons, as extensive enquiries in America has established that these particular areas are under-researched. Given the possibility that American machine tool designers were thin on the ground, at this stage in the thesis it is worth pausing for a moment to discover what engineers in the United States had actually achieved and what Burn and his Committee had actually seen.

Interchangeability and a report re-examined

Writers concerned with the history of the "American system of manufactures", such as the late K R Gilbert and Nathan Rosenberg, when discussing the question of interchangeable parts, usually quote from the "Report of the Committee on the Machinery of the United States of America", published in 1855. Over the years the main focus of attention has been on the section which relates to the Committee's experience at the Springfield National Armoury when arrangements were made for ten muskets manufactured between 1844 and 1853 to be dismantled, their separate components jumbled up, and then re-assembled without any problems of fitting being apparent. This much quoted part of the report has appeared in many standard texts and is used to illustrate how far American engineers were ahead in the areas of interchangeability and machine tool development in comparison to their British counterparts. However, it is not clear from reading this particular section of the report that the muskets scrutinised by the Committee during the exercise were stripped down to their very last detail and little knowledge is gained of what might have been considered an acceptable standard of tolerance. Closer examination of the wording may lead the researcher to interpret the information in a different way. For example, the report states:-

> With regard to the interchange of parts between the machine made muskets of the United States' Government, which has caused so much discussion, the Committee particularly interested themselves; and, with the view of testing this as fully as possible, selected with Colonel Ripley's permission ten muskets, each made in a different year, viz., 1844 to 1853 inclusive, from the principal arsenal at Springfield, which they caused to be taken to pieces in their presence, and the parts placed in a row of boxes, mixed up together. Then they requested the workman, whose duty it is to "assemble" the arms, to put them together, which he did - the Committee handing him the parts, taken at hazard, - with the use of a turnscrew only, and as quickly as though they had been English muskets, whose parts had been carefully been kept separate. .14.

Addressing this section of the report in isolation can lead to the wrong conclusions being drawn. If one continues through the next sentence it is possible that the researcher may reach a different opinion or at least keep an open mind, as the report goes on to say:-

> The only parts of the musket bearing any mark being the barrel and lock, which are stamped with the year in which they were made, and all these tried being of different years, the Committee took care that no barrel and lock bearing the same date, should come together again, and they were put together as follows, viz:-

The barrel of	1847	with the lock of	1849
"	1844	"	1852
"	1846	"	1848
"	1845	"	1844
"	1851	"	1850
"	1848	"	1853
"	1849	"	1845
"	1852	"	1847
"	1850	"	1851
"	1853	"	1846

> The other parts, having no distinguishing mark, were handed out at hazard. .15.

It is the reference to the Committee ensuring that "no barrel and lock bearing the same date should come together", with the list of how the experiment was arranged, which provides an important clue. This suggests that the complete lock was interchanged as a sub-assembly, rather than the individual component parts of the mechanism (typically twelve) being assembled separately. Another clue comes to light in the reference to both the barrel and the lock being "stamped with the year". This would suggest that the report writer was referring to a fully assembled lock, as it was the lock plate rather than the lock in total which was date stamped. At the time this was fairly common practice in the gun trade, as the lock plate along with the barrel, were the only major metal parts of the musket physically large enough to allow this. One further piece of evidence from the Committee's report which indicates that the locks were changed as complete assemblies comes from the following passage (although it does suggest that a small quantity of individual lock parts were interchanged separately):- "The experiment of interchanging was also tried on three locks with the most perfect success, the parts fitting as closely, and working as freely as before the interchange had taken place". .16.

Although the Committee gave the opinion after the interchanging exercise "that all the parts were as close, and the muskets as efficient, as they were before the interchange took place", they were honest enough to admit that they were "...diffident in expressing any opinion as to the comparative fit of these and the English rifle muskets, as none of them being viewers, they have no experience in examining muskets so minutely ..." .17. This is an important piece of information as it conveys to the reader that certain parts could readily interchange between weapons. However, the report does not inform us if there were any individual variations in component tolerance, and, if there were; what was considered acceptable. From the report it is clear that the Committee did not subject any of the parts which interchanged to a gauge test (they declared themselves inexperienced as viewers). Therefore, an important question regarding the degree of standardisation which was being achieved remains unanswered. Had British "Ordnance" viewers applied the strict standards of gauge tests to these parts as they had to those of the private contractors prior to the demise of George Lovell, one might ask whether the parts would have been accepted. Naturally one can only speculate as to the possible outcome but the question does once again draw attention to the severity of British viewing methods and also calls for a way of defining interchangeability so that the researcher is able to understand with confidence what levels of precision mid 19th century machine tools were able to achieve.

It would have been highly unlikely not to have found tolerance spreads in parts taken at random from a group of weapons manufactured over a period of ten years, particularly those which had been made prior to the middle of the century. The Committee's report tells us nothing of what might have been the maximum upper and lower limits of acceptance. Neither have we learned, particularly in the case of the individual lock parts, if tolerance standards were critical in every case. For example, if the lock was fitted as a sub-assembly then it would be important to get the size of the lock plate right to mate with the cut-out in the stock. On the other hand, it is quite possible that the dimension of certain internal lock parts would not be known if the lock was fitted as a sub-assembly. By bringing these relatively significant observations to the fore, it is hoped to focus attention upon the level of interchangeability achieved through machine manufacture in America at the middle of the century. Also it is important to discover if manual adjustments to machine made parts were still required. To do this it will be necessary to examine the 20th century work of Robert Gordon, as there are few clues in the Committee's report which allow us to judge the closeness of machine finishing.

Examining artifacts for evidence of machine finish

Robert B Gordon, by studying in great detail the material evidence of 19th century gun lock parts, and in particular the tumbler, has argued that American artificer skills had, with the introduction of interchangeability, increased rather than decreased. Gordon has found evidence to suggest that bringing lock parts to gauge by skillful hand filing continued in the national and the better private armouries at least until 1884. He further argues that "the tool marks and dimension measurements show that by 1850 artificers using hand files had learned to bring rough forged and machine parts of complex shape to final dimensions specified by gages to an accuracy of a few thousandths of an inch in routine production". By analysing tables and labour records at Springfield National Armoury, Gordon has calculated that "eighteen operations and seven types of power-driven machinery were used in making a tumbler, but one operation, hand filing by "first class mechanics", accounts for more than half the man-hours required", (54.5%). This was in 1864, ten years after the visit by the British Committee. .18. Gordon has further suggested that as the accuracies of machine made lock parts increased, so did the skills of the artificers, who by the 1870s could judge by feel and fit when gauging measurements to better than 0.001 inch. .19.

If Gordon, a professor of geophysics and applied mechanics, is correct in his laboratory assessment of the tumblers (his findings have not been challenged), then the mental picture conveyed by successive commentators over the interpretation of the Committee's report, particularly with regard to metal components, has brought about a somewhat exaggerated impression of what level of precision the machine tools of the day could achieve. Also it would appear that the skill of the artisan has been omitted from the interchangeability debate.

A question of misinterpretation?

Examining in some detail what the Committee had actually witnessed and reported with regard to the interchangeability of the ten weapons will, hopefully, alert future researchers not to always accept the written word until an examination of the artifact has taken place. The fact that many writers and historians have not fully explored or thought deeply about what the Committee had actually reported has left a gap in our knowledge. In consequence, the conclusions drawn, although seemingly correct, were based on a misinterpretation of the documentary evidence. As these conclusions have persisted and have remained unchallenged for some time, the opportunity has been taken to carry out a physical examination of the assembly procedures of a number of lock mechanisms similar in age and pattern to those in the Committee's report. Using the information gathered from this present-day experiment, and focussing the investigation upon the physical aspects of the tests devised by the Committee to determine the claims of interchangeability betwixt the ten weapons manufactured between 1844 and 1853, a clearer picture emerges of what was actually witnessed.

Research has indicated that the most likely weapon the Committee would have seen manufactured during their visit to Springfield was either the 0.54" U.S. Army rifle model 1841 or the 0.61" model 1842 musket. Both of these small arms employ a lock mechanism similar to those commonly in use at the time in Europe. Armed with this knowledge, the objective was to investigate the validity of the statement that assembly of a Springfield small arm (assuming that the lock mechanism was broken down to its individual component parts) could be achieved "with the use of a turnscrew [screwdriver] only".

The lock mechanisms in question employ a main spring which can only be fitted (or removed) under tension. To accomplish this a special tool known as a spring cramp (Figs.23-27) (mainspring vise in America), is used to compress the spring. .20. When dismantling a lock it is normal practice to place the spring in the cramp and tighten the device to the required tension, thereby compressing it. The spring can then be removed and left gripped in the jaws of the cramp until the lock is re-assembled. As the Committee's report makes no mention of such an operation taking place, it would seem safe to assume, from the statement "with the use of a turnscrew only" that the Committee had witnessed the assembly of weapons with locks which had not been broken down into their twelve individual component parts. Therefore, what the Committee had seen was most likely a weapon being assembled with a pre-constructed lock as a sub-assembly. As the majority of commentators have repeatedly used this section of the Committee's report to indicate the advanced level of interchangeability reached by American engineers by the middle of the century, it seemed appropriate to re-visit the experiment on which this information was based, not only to put the record straight, but to help clarify aspects of the mental picture of machine tool accuracy already created.

It should be remembered that the Committee when visiting Springfield saw two types of material being worked, wood and metal. Like Whitworth before them, the Committee were highly complementary about the novelty and accuracy of the sequence of wood-working machines for producing gun stocks. This aspect of the visit, as pointed out in the last chapter, allowed an engineer like Anderson to further communicate his enthusiasm for the novelty of the system through lectures to learned societies on his return to Britain. However, what seems to have been forgotten is that wood is easier to machine than metal and the whole debate over the standard of accuracy achieved by mid 19th century machine tools generally had become confused, until Gordon took a scientific look at some metal artifacts.

A recognition of American talent

It should be clearly understood that the detailed examination of the above section of the Committee's report, containing the experiments between muskets of different vintage, does not detract in any way from the considerable contribution towards interchangeability made by American engineers like Whitney, North, Blanchard and Hall, to name but a few. These men had helped perfect precision engineering over a period of many years by evolutionary experimentation and accurate gauging, with minute attention to detail. Perhaps the most significant contribution which gave rise to the level of precision required for interchangeability came from the design, development, and introduction of good quality machinery into the manufacturing process. Of the many great American engineers, John H Hall (1781 -1841) stands out not only as a man of considerable inventive genius but also as a man of vision and determination. Although under great pressure to fulfil a government contract for one thousand of his breech loading rifles, signed in March 1819, Hall persevered with constructing and designing the production tools and machinery which he required to manufacture these weapons with his "New System" of interchangeable parts. As a result the contract was not completed until December 1824. .21.

Hall appears to have clearly grasped the concept that to have a manufacturing system which produced parts consistently to a repeatable standard required not only machinery designed with solid and stable frames but also balanced drive pulleys and shafting. He also sought to reduce the incidence of human error by advocating precision methods of measurement, where calculations were derived from a single point on the work piece. .22. In many ways the achievements of American engineers are quite remarkable as they endeavoured to solve problems of precision and standardisation before the science of the most crucial piece of the metal machining process, the carbon steel cutting tool, was understood. According to Tom Rolt, "The world's first improved tool steel was produced in 1868 in a little iron works near Coleford in the heart of Gloucestershire's Forest of Dean. Its inventor was Robert Forrester Mushet (1811-1891), the son of a pioneer Scottish ironmaster, David Mushet ..." .23. Therefore, for American engineers to have reached the level of standardisation they had by the time the 1854 Committee visited Springfield suggests they were encouraged rather than obstructed. The motivation would seem to stem from the initiative of the American Government, who, as early as 1815, had specified that parts should not only interchange between individual weapons within a contract but also with all similar small arms produced at the other national armouries. .24.

The placing of machinery contracts

In placing contracts with the various machinery manufacturers the Committee had taken a long term view of their responsibilities, arriving at a number of logical conclusions in the choice of suppliers. For example, they gave the following reasons for choosing certain companies which would not necessarily be the fastest to deliver:-

> In making contracts the Committee have endeavoured to secure against confusion by having dealings with as few firms as possible, and those of highest character; and they trust that

> though the machinery ordered will not be completed so soon as they could have desired, when it is delivered and set to work it will prove good and efficient, and by superseding hand-labour, be the saving of large sums to the British Government, and, at the same time, add to the uniformity and stability of the articles manufactured by its assistance. .25.

Apart from their prime objective of equipping Enfield, the Committee had also to purchase suitable machinery for the Royal Laboratory and Carriage Department at Woolwich. This amounted to 17,200.28 dollars for card cutting, wood cutting, tension & torsion, tin working and percussion cap machines. The Committee took the view when selecting machines for Woolwich that they were not "guided by finish or solid construction". They were more interested in machines that were "most ingenious", reasoning "should it be necessary, more stable machines can be constructed". It would seem from the evidence that the Committee had based its decision upon the observation that "all the machines used for wood work in the United States are roughly constructed, and would not bear comparison in stability and appearance with the highly-finished iron machinery of England". .26. While these might seem to be perfectly reasonable and justifiable motives for adopting this stance, it did, however, give the Committee the advantage of securing machinery which had already gone through the expensive research and development process. This would, no doubt, allow scope for cost effective modifications and improvements at a later date in Britain.

The deliberate policy of selecting the "most ingenious" machinery, even if it proved to be mechanically flimsy, suggests that there was nothing comparable operating in the British gun trade at the time. If, indeed, there was, it would certainly have been known to Anderson, who in March 1853 had made an extensive tour of British manufacturing industries and drew up a report of his findings for "Ordnance". The tour had clearly made a lasting impression on Anderson who repeated his findings a year later when he stated that the military bayonet and musket manufacturing industries were "... in a low mechanical state, and at least 50 years behind most of the other branches of manufacturing industry which we have been examining". However, he went on to say that "... the tool makers of Leeds and Manchester, steel pen and wood screw making of Birmingham. Those we were very much pleased with". Interestingly Lieutenant (later Captain) Warlow R.A. a member of the three man Committee to the United States of America, had accompanied Anderson on his tour of the British manufacturing industries. It is therefore likely that Warlow's presence would have increased the Committee's overall knowledge of the shortcomings of machine tool usage in Britain and strengthened considerably their position when deciding the most suitable equipment to purchase. .27.

Given the fact that the Committee had eventually been allowed an almost free hand by the Board of Ordnance to purchase appropriate machinery, they may have formed the opinion that they were in a controlling position to provide fast-track solutions to engineering problems at home. To achieve this, and to remove the need for lengthy and costly specialist machine tool development programmes, the British Government, through the expertise of the Committee, could take a short cut and bring its ordnance factories up to date by buying equipment off the shelf or having it made to order. The Committee's decision to purchase machinery which was ingenious although flimsy in construction allowed them further opportunities to present British engineers with physical examples of machine tools. This had the distinct advantage of eliminating problems which can easily occur after a fact finding visit, through misunderstandings, inadequate descriptions and incorrectly taken dimensions. Having actual physical examples of machine tools to examine could also provide a less costly way of encouraging British firms to carry out improvements and modifications. This would have been particularly necessary if "Ordnance" for any reason lacked the ability or capacity to complete such work in-house. Examples such as this provide hard evidence of technological diffusion, demonstrating one of the many ways which allowed technical transfer to take place between countries through the purchase and movement of machinery and the evolutionary process of adapting tried and tested ideas.

What the Committee had seen gave them confidence to sign contracts for a considerable quantity of machine tools. Four tenders were accepted from the Ames company, mainly for stocking machines and gauges, the total cost being 46,844.62 dollars. The first of these tenders was for a sequence of fifteen stocking machines, as opposed to the sixteen used in the process at the Springfield Armoury. Buckland who had been requested to design the machines within the terms of the contract to accommodate the Enfield pattern 1853 musket stock, was of the opinion that one operation could be left out. However, when studying the third tender for evidence of machines to supplement and increase the daily output of the fifteen, it appears that a further two different types were introduced. Unfortunately it is not clear from the construction of the tenders (machine numbers having been left off on the third and wording being ambiguous) whether Enfield was to have a sequence of sixteen or seventeen machines. The total quantity of machines purchased from Ames, not counting gauges and a piece of equipment for testing power, amounted to twenty-two.

It is interesting to observe, from the text of the Committee's report, that clues are beginning to emerge which couple the design of the rifle to the economy of production. For example, the Committee, when submitting the pattern 1853 to the armoury at Springfield, "deem of sufficient importance to mention" the "criticism of the officers and others" concerning three areas of design, one of which related directly to ease of manufacture. It was pointed out that the design of the trigger-plate and trigger-guard on the American musket was "... preferable to that of the English one, both as a part of the arm, and as an article to be manufactured by machinery". .28. This, therefore, implies that, if the arms designer and the engineers responsible for the design of machinery and the factory lay-out could come together prior to commencing the development of a new weapon, it would be perfectly feasible to save considerable sums of money on capital equipment and costly production operations or processes. However, as has already been highlighted in the thesis (and as will be discussed in greater detail in the following chapter), there is little evidence to suggest that these particular aspects of weapon design relating to ease of manufacture were ever seriously pursued, either by the Board of Ordnance or its successor, the War Department, during the remainder of the 19th century.

Three contracts were signed with Robbins & Lawrence for a quantity of 129 machines to carry out the different milling, drilling and cutting operations required in the production of the Enfield pattern musket. The total cost of this machinery which included some specialist tools came to 41,334.60 dollars. Curiously it was the Ames company, rather than Robbins & Lawrence, who tendered and obtained the contract for a complete set of 115 jigs and gauges to measure every aspect of the Enfield musket, not just the stock as might be implied from Ames's construction of the wood-working machinery. This might indicate that the Ames company, after securing the services of Cyrus Buckland, may have been able to allow some of their craftsmen with higher skills to concentrate more fully on the very demanding and time consuming task of gauge making. On the other hand it may simply have been the case that Ames had greater capacity to accomplish the work within the required time-scale of twelve months. Robbins & Lawrence had contracted to supply the bulk of their orders within nine and fifteen months respectively. This might suggest that they had sufficient work in hand and did not wish to take on the added expense of extra skilled staff for a relatively short period.

Before leaving America towards the end of August, the Committee received a further tender of 38,784.37 dollars from Robbins & Lawrence to supply a barrel making plant for the Enfield musket.

As the Committee considered this to be a "considerable sum of money" they resolved to leave the offer open until they had the opportunity to discuss the matter with the Board of Ordnance upon their return to England. Nevertheless, the Committee took the opportunity to venture the following opinion in their report:- "that it would be much safer to get such a plant of machines from Messrs. Robbins and Lawrence, who have studied and practised the manufacture of barrels, than from those who have less experience in this branch of the trade"... .29.

A new and different world?

The Committee had spent almost five months in America viewing a wide cross-section of manufacturing establishments, their processes and production techniques. From the Committee's report, it is evident that in most instances they were impressed with what they had seen. The contrast in the level of mechanisation between British manufacturers and the selected industries of their tour had caused them to write a futuristic warning:-

> The contriving and making of machinery has been so common in this country, and so many heads and hands are at work with extraordinary energy; that unless the example is followed at home, notwithstanding the difference of wages, it is to be feared that American manufacturers will before long become exporters not only to foreign countries, but even to England, who for want of energy in improving their machinery and applying it to special purposes. The advantages in a manufacturing point of view are all on the side of our countrymen, and there is nothing made in which they ought not to be able to undersell. .30.

Looking at what remains of British industry today, it would seem that the Committee's advance warning has not been heeded by industrialists or successive governments. Nevertheless, they had experienced a vision of industry (albeit a narrow selected sector) which by British standards must have appeared highly advanced, particularly that which they had witnessed in the American national armouries.

The Committee had been staggered by the working conditions within many of the factories they had visited, leading them to remark "The care almost universally bestowed on the comfort of the workpeople, particularly attracted the notice of the Committee; clean places for washing being provided, presses to contain their change of clothes, and an abundant supply of good drinking water, in many cases cooled with ice". .31. During their travels, the Committee had observed a feature of many of the public and private manufacturing plants they had visited which set them apart from their British counterparts. This was investment in a good working environment, indicating an air of confidence amongst American industrialists who had seemingly taken a long term view and were planning for future expansion. The Committee's opinion would seem to confirm this notion as they suggested the improved working conditions were due to the "speculative character of the proprietors". A prime example of speculation and forward planning was observed when they visited Colonel Colt's new factory in Hartford, which, at the time, was under construction. The Committee reported that they were "astonished" by the magnitude of the buildings, particularly when they learned that it was planned for the factory to be the "largest and finest armoury in the world" when completed, being twice the size of the proposed Enfield plant.

Of course one must be careful when analysing such reports as that of the 1854 Committee to America as it is possible to draw the wrong conclusions. Their tour had been specifically planned to visit those manufacturers which had invested in novel types of machinery. Therefore, it is not possible to discover the general level of mechanisation employed throughout the industries of the United States. In fact Fitch had suggested in his 1882 Census (debated above) that the general level of mechanisation in American industry was not as great as popularly thought. Nevertheless, and in contrast to Britain, one can not escape the fact that, when reading relevant documentation of the period, there was in America a genuine air of enthusiasm and excitement for novel ideas. This had no doubt been encouraged by the pioneering work of the national armouries in their quest for standardisation. The situation is probably best summed up by the Committee when they were prompted to write "the avidity with which any new idea is laid hold of, and improved upon, a spirit occasionally carried to excess, but upon the whole productive of more good than evil". .32. From the recording of such comments it it would seem that the Committee had been "intoxicated" by their visit. This no doubt had helped to further the notion in Britain (debated in the last chapter) that the machinery which was on order for Enfield was common-place in the United States.

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.32. Ibid., pp.630-632 (84-86)

WHAT WAS RESPONSIBLE FOR DELAYING THE INTRODUCTION OF NEW METHODS OF WEAPON MANUFACTURE IN BRITAIN?

To answer this question it will be necessary to examine the procedures employed by the Board of Ordnance in the design and development of new weapons. It will also be necessary to discover whether British engineers possessed the essential skills, vision and inventiveness to have developed a system for the mass production of small arms manufactured with interchangeable parts, prior to the British Government's purchase of machine tools from America. However, while ease of manufacture and assembly is the Holy Grail of every plant manager, it is not necessarily correct to imagine that the introduction of a product based on interchangeable parts is the ultimate in engineering design. The reasons for this seeming paradox will be investigated within the confines of this chapter through an examination of the "Ordnance" system of design and procurement of new weapons.

<u>Ease of manufacture and assembly</u>

Research to date has not uncovered any evidence which would suggest that, in the first half of the 19th century, the Board of Ordnance had actively considered a change to the method by which new weapons were selected in order to ensure that designs included features improving ease of manufacture, assembly and repair. Furthermore, there appears to have been little or no thought given to a coordinated or collective approach to design which would have encouraged a more economical mode of manufacture. Engineers had been aware for some time of the benefits of an integrated approach to product design and manufacture. The respected "Ordnance" engineer John Anderson was well aware that weapon parts could be made more cheaply without losing their efficiency if designed with ease of manufacture in mind. In evidence to the Select Committee of 1854, Anderson demonstrated his concern for economical production methods by giving a hypothetical example of being ordered to manufacture a gun by machinery to a certain pattern, stating "I would study to carry it out; but I should not be doing my duty if I did not say, "By this plan you may do it much cheaper". .1. Moreover, it is known, from the results of research carried out and highlighted throughout this thesis, that there were many complex issues surrounding the subject of economical weapon manufacture which had influenced the judgement of the Board of Ordnance. The political pressures placed upon Parliament by the private gun trade, and the long period of relative peace following the Napoleonic Wars were just two. As we have seen in Chapter Eight, it was the Crimean conflict which finally acted as the trigger for a more efficient means of military weapon manufacture by machine methods. However, research has indicated that these issues did not lead immediately to a system which deliberately set out to consider ease of manufacture at the point of product design.

Prior to the outbreak of hostilities with Russia, the annual output of arms from the Enfield factory was relatively small and we have seen that the bulk of military weapon's in fact, were produced by manual methods by private sector contractors. Under such an arrangement, the majority of the overhead cost would have been shouldered by the private sector. Therefore, there would have been little benefit for "Ordnance" to have pursued the preparation of new weapon designs which could be manufactured more efficiently and cheaply by machine methods. Conversely, there would have been little incentive for the private contractors to have recommended improvements in weapon design. For them, stability of product for as long as possible with minimum amount of change was all important.

Given these circumstances it would seem reasonable to conclude that the maintenance of the "Ordnance" contract system of arms procurement helped delay not only the system of machine intensive production but also the introduction of weapon designs which were easy to manufacture. One might therefore argue, no machines, no need to modify the product. The corollary of this would seem to be to install new machines then redesign the product for ease of manufacture. But was this true in the case of the newly installed American machine tools at Enfield Lock, which had been specifically designed to manufacture a standard weapon with interchangeable parts.

New machines at Enfield

The machine tools purchased from America by the three man Committee were installed in a new purpose built machine room at Enfield Lock between 1855 and 1856. Through their introduction it was hoped to secure continuity of small arms supplies for the armed forces by dramatically increasing the manufacturing capacity of the factory. Because the new process was based on a system of standardised interchangeable parts, the Board of Ordnance were also expecting to see a number of economic benefits. These would range from improvements in weapon assembly times, reduced labour content per weapon, simplicity of part storage and improved stock control. There would also be benefits for the military once the new manufacturing system came into service. Small arms constructed with interchangeable parts would have simplified battlefield repairs, allowing armourers with less skill and training than their predecessors to do the work. Before interchangeability, components requiring replacement at the front had to be individually made and fitted. This was costly and time consuming.

The introduction of the new machine tools opened up further manufacturing opportunities. There was much to be achieved by ensuring the design of future weapons took into account the limitations of machines to follow awkward shapes. "Ordnance" were now placed to evaluate and alter the design of those parts of the arm which had evolved over many years prior to the machine tool era. Several of these items, as Anderson had already pointed out, had complex shapes which were not essential to the effective and efficient performance of the weapon. This latter aspect will be examined later to discover if "Ordnance" fully appreciated the economic benefits to be gained from a programme of integrated product design linked to ease of manufacture.

<u>New machinery, old style weapon</u>

The new machine tools installed at Enfield had been built to accommodate the existing pattern 1853, the design of which had evolved from earlier weapon types. In other words, the "American system" had been adapted as far as possible to fit a surviving

British weapon. The pattern 1853 had been developed as the result of an open competition in 1852 and it was not until 1854 that the British Commission to America placed orders for the new machine tools, clearly demonstrating the lack of connection between weapon design and the new manufacturing process. Looking at the weapon's historic and evolutionary development, parts of which can be traced back to 17th century France, further confirms that the approach to manufacturing lacked coordination with design. From an examination of a range of artefacts manufactured at Enfield it can readily be deduced that the shape and design of certain key components of the pattern 1853 had not been modified to favour more cost effective production.

As the timing of the factory alterations and the installation of the new equipment at Enfield coincided with the Crimean War, it might be argued that "Ordnance" did not wish to experiment with weapon design changes to facilitate further manufacturing improvements. Such a decision would have seemed rational at a time when the supply of weapons to the front was absolutely crucial. However, if this was the reason, one would have expected the emergence of a strategy aimed at weapon design improvements to assist manufacture and assembly to be pursued in the more relaxed atmosphere when hostilities ceased. Later in this chapter it will be suggested that this opportunity was never grasped.

Typical methods of weapon improvement

During the early period and until quite late into the 19th century, refinement of small arm's design usually came about through individuals suggesting improvements. In January 1885 the

Inspector General of Musketry, Colonel Harrison Trent of the School of Musketry, Hythe, Kent, wrote to the Under Secretary of State for War in support of James Aston, the Civil Master Armourer, who was claiming recompense for his inventions. Between 1855 and 1882 Ashton had submitted some fifteen improvements and modifications to various small arms in service, several of which had been adopted by military. In fact, Aston had been paid £100 for three improvements he had submitted between 1855 and 1856. These consisted of a new pattern ramrod with a jag head to allow easier removal from the stock, an improved pattern lock cramp for removing the main spring and a snap-cap to fit over the nipple. All these improvements were for the Snider rifle, although the cramp could be used for the removal of similar main springs from other weapons which employed the same type of lock mechanism. .2. Post production modifications like the ones submitted by Aston arose from the practical experience of handling the weapon in the field and were normally designed for ease of use, not ease of manufacture. If the modification submitted could improve the weapon without both a significant on-cost and the creation of other difficulties, then its introduction would normally be given serious consideration by "Ordnance" or the War Office.

It was not unusual for good ideas and designs to be taken from other manufacturers. Sometimes this came through advertisements for weapon selection by open competition or by inventors sending samples to "Ordnance" for evaluation. On occasion "Ordnance" would obtain the weapons directly for examination. In such circumstances "Ordnance" might negotiate a licensing or royalty agreement for incorporating these changes into their own weapons. New ideas were not just limited to British inventors. In an endeavour to keep abreast of small arms development in Europe, "Ordnance" dispatched George Lovell to Germany in 1849 to examine recently introduced weapons. On his return to England he was ordered to prepare a number of muskets and rifles based on French and German patterns. Subsequently Lovell was again sent to Germany and instructed to bring back a sample of their latest breech loaders and also a French Minie rifle. .3. However, there is no evidence to suggest from an examination of the available reports regarding weapon change and modification that the alterations made bore any relationship to ease of manufacture or assembly. They were primarily introduced to improve aspects of battlefield handling such as firepower, range and accuracy.

Research has shown that many people were under the impression, and for that matter still are, that superiority of a particular weapon was due to the clever design and development of an individual armoury like Enfield. For example, in the House of Commons in June 1861 a leading article from the Times newspaper was quoted in debate. The article discussed the effectiveness of the Enfield pattern 1853 rifle during the Crimean War by saying it "Smote the Russians like the Hand of a Destroying Angel". .4. While the prose may seem somewhat florid and patriotic, no doubt the report helped spread the notion that the RSAF at Enfield had designed a superior weapon, which completely ignored the evolutionary process which had brought the pattern 1853 to its eventual state of development. A further aspect which seems to have been overlooked is that the vast majority of pattern 1853s supplied to the front line during the conflict were not manufactured at Enfield at all. At the time when Britain entered the war in the Crimea in March 1854, the Commission to the United States of America had only just set out on its fact finding mission. Orders for machine tools to equip the Enfield factory were therefore not placed until later that year. The time then taken for the machines to be manufactured, shipped and installed meant that the plant did not come fully on-stream until January 1857, some ten months after hostilities had ceased.

Methods of weapon selection

The second half of the 19th century in Britain saw a marked leap in the level of innovation in the evolutionary development of the small arm, resulting in a narrowing of focus towards an improved performance standard of military weaponry. This was accomplished by a method of selection through open competition between gun-smiths and inventors, rather than setting new design and performance criteria in the form of a specific research and development project. The advantage of the system of open competition was that the War Office incurred minimum development costs; the disadvantage was that little attention was paid to ease of manufacture and assembly. As has already been pointed out, the introduction of the "American system" at Enfield in the mid 1850s with sequenced machinery producing arms with interchangeable parts, had little effect in moving "Ordnance" towards a policy of integrating weapon design with ease of manufacture. To discover why the opportunity to produce weapons more simply and economically had seemingly been ignored, it will be necessary to examine in some detail the reports of the

Ordnance Select Committee on Small Arms which took place as the second half of the century got under way. In so doing, we will gain a better understanding of the criteria used by "Ordnance" when selecting the next generation of weapons.

At the time of the American Civil War there was considerable controversy among high ranking British officers and government officials over the effectiveness of the breech loading rifle in use with the Federal Troops. On 13th June 1864 the British Secretary of State for War, Lord de Grey, set up a committee to investigate the usefulness of equipping the infantry with breech loading arms. Grey himself had considerable reservations about the breech loader as he was of the opinion that "troops thus armed might fire away their ammunition too rapidly, and thus increase the difficulty of supplying them with ammunition during action, and render necessary the employment of a larger amount of transport than would otherwise be required". .5.

The Committee met for the first time on Monday, 27th June 1864 under the Presidency of Major General Russell C.B. to consider the evidence of a number of army officers and experts. Lieutenant Colonel Gallwey R.E. and Captain Alderson R.A. attended and informed the Committee that during their recent visit to America they had discovered different opinions among the military authorities as to the value of the breech loader. Unfortunately these officers were not able to give a personal account of the breech loading rifles in action as they explained, "the United States Secretary for War refused us permission to accompany the army on active service". Gallwey and Alderson said that several

General and Staff Officers which they had interviewed "seemed to hold the opinion that breech-loading arms, in the hands of selected bodies of troops, would be productive of good results". .6. A Brigadier General Seymour, a very experienced soldier by all accounts, who had acknowledged the usefulness of the Spencer breech loader at the battle of Oluslee, was "averse to breech-loaders as a general weapon for infantry. He advocates the arming of flank companies or other picked bodies with special arms; but for the main body of infantry he would prefer a simple smooth-bore musket". The reasons for this preference was thought to be due to "the general nature of the country, which being densely wooded, only admits of actions being fought at close quarters". .7. On the other hand, Brigadier General Terry reported that, when he was in command at Pocotaligo, his troops were suffering considerably from enemy fire. He therefore ordered a Colonel commanding a regiment whose flank companies were armed with Sharp's breech loaders to "push forward those companies into the best cover they could find, and open fire on the enemy". It was said that "The men knowing that this was done to test the value of their arms, answered with a cheer, and advanced in skirmishing order, covering themselves as best they could. In a short time the enemy's fire was subdued". .8.

The second meeting of the Committee took place on Thursday, 30th June 1864, when Brevet Colonel Dixon R.A., Superintendent of the Royal Small Arms Factory, Enfield was examined. It was reported that Dixon "Considers breech-loading practicably objectionable; the prime cardinal difficulty, however, being connected with the ammunition". His main objection concerned the safe storage of certain types of breech loading ammunition which had its own "means of combustion". .9.

A Major Young R.A. was examined by the Committee and reported that during his foreign tour of 1861 he had been present at the the autumn manoeuvres of the Prussian troops on the Rhine when the breech loading needle gun was used. There he had been told by Austrian officers "that the arm had been discarded from their service; and the Prussians themselves would also discard it were they not so entirely committed to its use". He also voiced similar objections to those of the Secretary of State for War when he explained "breech-loaders are not adapted for general service, but only for trained men and for special occasions; and that they are a temptation to young soldiers to fire away all their ammunition". .10.

James Burton, the former Master Armourer at Harpers Ferry who had been brought from America to oversee the installation of the new gun making machinery at Enfield, told the Committee that breech loaders "are the favourite weapons of the Federal cavalry; and that the general impression in the United States is that the system will be universally adopted". This, incidentally, was also Burton's personal opinion. .11.

The Committee appear to have been extremely thorough in their investigation, even going as far as to read extracts from a report some fifteen years earlier (dated 19th October 1849) by the late Inspector of Small Arms, George Lovell. Here it was reported that Lovell had received assurances from the military authorities of the effectiveness of the Prussian breech loading needle-gun when used during the war with Denmark. Lovell had reported in his evidence that the "...advantages claimed for it [needle-gun] being that it has little or no recoil, can be fired 12 times a minute, and can be fired and loaded by a soldier even when lying down or presenting his bayonet to the enemy". .12.

Major General Hamilton C.B. late Military Attache to the British Embassy in Berlin and at the time Vice-President of the Council of Military Education, reported that he had received "most satisfactory accounts of the needle-gun ... the arm has been much improved there during its 16 years since introduction, and is now the only rifle used by the Prussian infantry". It is also interesting to note that Hamilton went on to suggest that he had "Never heard of any accident caused by the ammunition containing its own ignition, or of any escape of powder from the gun", this, had been a major fear expressed in evidence by Colonel Dixon. Hamilton also stated that he had "Never heard of any difficulty in keeping up supplies in the field". This was the basis of an earlier objection to the adoption of the breech loader by the Secretary of State for War, Lord de Grey. .13.

After completing four meetings between the 27th June and the 11th July 1864 and having listened carefully to the evidence of the various experts and military officers, the Committee "beg to report their opinion in favour of arming the Infantry wholly with breech loading arms". .14. Although the Committee, which comprised of five Colonels under the Presidency of a Major General, took the collective decision to recommend that breech loaders should be issued to the infantry, it can clearly be seen, from the range of evidence given, that opinions were divided as to the usefulness of this weapon. While this particular debate highlights the necessity for training military personnel in the use of any new weapon and identifies potential logistic supply problems for the army, it also, in reality, demonstrates quite graphically the lack of any sort of planned weapons development programme. It would therefore appear that the Committee of 1853 under John Anderson, Superintendent of the Ordnance Factories at Woolwich, who called the method of procuring small arms "heterogeneous in its character", might have used the same terminology had they been asked to investigate the then current method of designing and developing small arms for the British Army.

An opportunity to change

As we have seen earlier, under the "Ordnance" contract system of arms procurement which had operated throughout the first half of the century, Enfield had effectively been denied the ability to produce weapons on a large scale through political pressure exerted by the private sector on Parliament. It can also be seen from Lovell's evidence to the Select Committee of 1849 that he was opposed (at least on the surface) to the expansion of Enfield's manufacturing capabilities. These measures had allowed the factory to concentrate on a policy of keeping a "check" upon the private gun trade in both Birmingham and London. However, as we have already discussed, with "Ordnance" in firm control of military small arms manufacture as the second half of the century progressed, Enfield's annual output had increased dramatically. Between 1858 and 1864 the factory produced in excess of 505,000 guns and pistols. Having the potential to produce such large volumes, it might seem curious that savings were not apparently being considered by making simple design changes to the weapon, particularly those which Anderson had identified earlier. .15. With the acceptance of the breech loader as the new weapon for the military, there was a clear opportunity to maximise the efficiency of the recently installed plant at Enfield. This could have been partly achieved by specifying a simple manufacturing and assembly clause in the open competition document which invited tenders for the modification of the pattern 1853 to a breech loader. Of course there is the possibility that the War Office, having taken responsibility for arms procurement, was intent on containing the conversion cost of the Enfield rifle in the short term by stipulating in the tender notice that the alteration was "not to exceed £1 per arm". .16.

As discussed above, from a rudimentary examination of the lock mechanism of the pattern 1853 Enfield rifle, the shape and design of this component had changed little from its origins in 17th century France. Carrying out the modification to a breech loader on the Snider principle would mean that the lock design would continue into the second half of the 19th century. Therefore, there can be little doubt that successive Master Generals of Ordnance and those in authority at the War Office had not considered ease of manufacture and assembly. Consequently, it is probably fair to speculate that, as most of these men came from military and political backgrounds, their interests lay mainly in a weapon's range, accuracy and fire-power, rather than the niceties of manufacturing efficiencies. For example, Viscount Henry Hardinge in 1852 had succeeded Henry William Paget Marquis of Anglesea as Master General of the Ordnance. Both men had served with Wellington in the Peninsula Wars and both had interwoven their military careers with various political appointments. Wellington, in his long and distinguished military and political career, had himself been Master General from 1819 to 1827 and Prime Minister from 1828 to 1830. .17.

From 1683, the office of Master General had been filled by a senior member of the military holding a Cabinet seat. This practice continued until 1828. O F G Hogg has said of the situation "The office (of MGO) therefore, came to be regarded as a prize for the most distinguished soldier of his time". .18. It would therefore seem fair to conclude that these particular occupations were hardly the best qualifications for appreciating and understanding the intricacies of production engineering and the cost benefits to be gained from a weapon development programme which considered ease of manufacture and assembly.

A different design and development philosophy

In contrast to British "Ordnance", the American national armouries demonstrated a greater awareness of the need constantly to review and to develop methods of efficient arms production. Merritt Roe Smith, when discussing interchangeability, pays tribute to John H Hall who "stood foremost among those who combined inventiveness with entrepreneurial skill in blending men, machinery, and precision measurement methods into a workable system of production". Although Roe Smith has recognised that Hall failed to "...achieve significant economies of scale" when he produced the first "...fully interchangeable weapons in the United States", he does however see him as a "...pivotal figure in the annals of American industry". .19. An illuminating point concerning Hall's expertise came from a contemporary, Eli Whitney Blake, the nephew of Eli Whitney. Meant as a criticism, he stated that Hall "had purposely designed his rifle for interchangeable production", suggesting that "whenever insurmountable technical difficulties arose, the inventor eliminated them by changing his model accordingly". .20. Without apparently knowing it, Blake had put his finger precisely on the point, that of altering the design of a product to accommodate the needs or inadequacies of a production system. Roe Smith has stated that there were eleven changes made by Hall to his rifle between 1823 and 1841 which were generally not "aimed at circumventing technical production problems". This might seem somewhat ironic as Roe Smith implies that the changes, rather than simplifying machine operations, "...demanded even greater machining capacity". It is, however, conceivable that some of the early changes made by Hall were to accommodate variations from the pattern which occurred at the time when he was making certain parts by hand for the first contract guns which was prior to his machinery being completed. These alterations would probably have been necessary to even out spreads created by hand finishing, thereby setting a standard for the machines. This may have been the root of a number of contract difficulties, as it is known that not all the 19,680 weapons made under Hall at Harpers Ferry were completely interchangeable. Roe

Smith has pointed out that the "operating parts of the Hall rifle were more numerous and complex in design than those of the common military musket". This, he suggests, eventually provoked the War Department to cease production of Hall's weapon at Harpers Ferry in 1844. .21.

The evidence produced by Roe Smith would seem to confirm that Hall played a "pivotal" role not only in the development of interchangeable part manufacture but also in the acceptance of the notion that product design could be changed to accommodate the then current production technology. This latter point must be completely understood by any designer wishing to have his product made in a standardised way by mass production machinery. It is a fundamental principal that, if the technology of mass production is to work efficiently, product designers must have some knowledge of the mechanical capabilities of the machines on which their designs will be made. There is usually a strong requirement for good levels of understanding and cooperation between production engineers and designers at an early stage in the product development cycle. These concepts are certainly understood in engineering circles in the 20th century, although it would appear they had not been universally grasped in the 19th. Furthermore, those in powerful administrative positions within British "Ordnance" were either ignorant of the concept of designing a weapon for ease of manufacture or were ignoring it.

Unlike his British "Ordnance" counterparts, Hall was uniquely positioned to take advantage of being both a weapon and a machine tool designer and of having the good fortune to be given a complete contract by the U.S. Government to develop his breech loader. In contrast, the method of arms procurement operated by British "Ordnance" had divided the manufacture of a weapon between several different firms. These establishments were generally small and manufactured individual pieces of the weapon, having no responsibility for its design. Under such a system it was not possible to coordinate the skills of the product designer and the machine tool engineer. The luxury which Hall enjoyed simply did not exist in Britain. However, while it would appear that Hall had either consciously or unconsciously raised the awareness of his contemporaries to the fact that the product could be modified to assist ease of manufacture and assembly, there does not seem to be an overwhelming amount of evidence to suggest that this notion was immediately taken up by American arms makers.

It has been suggested by Professor Tim Putnam, that "...the model 1842 U.S. army rifle unlike the P1853 Enfield, had been designed to make assembly easy". .22. This would appear to be a somewhat curious statement to make, as the lock mechanism on this weapon is almost identical to the pattern 1853 Enfield (Fig.28). However, a careful comparison of the shape of the hammer on these two weapons will reveal that the U.S. model 1842 has a much simpler profile for a machine to follow. This would make the part more economical to produce by reducing the manufacturing time. Therefore, could it be that Professor Putnam has inadvertently confused the terminology in suggesting that the model 1842 "had been designed to make assembly easy", when the operative word should have been manufacture?

It has been stated above that the "Ordnance" engineer John Anderson had suggested to the Select Committee of 1854 that parts of the pattern 1853 lock could be simplified to bring about cost effective improvements in manufacture. Studying the evidence within the report makes it clear that one of the parts Anderson was referring to was the hammer or cock. During the questioning of Anderson a most important piece of information is revealed which categorically confirms that, by the middle of the century, engineers of his calibre were perfectly aware that there was considerable economic benefit to be gained from modifying the product to fit the machine. After much debate within the Committee on the subject, the question was put to Anderson:- "You are to be allowed to alter the gun completely from the original pattern, to make it suit the machinery, and this is all founded upon your hopes and wishes?" Anderson replied "Nothing has been said to me about doing that; that has only been spoken about in this Committee-room. I stand by what I said on that matter". .23. This implies that engineers, although aware of the advantages of designing product for ease of manufacture, had not been invited to do so by "Ordnance". What is perhaps more significant about this piece of evidence is that the debate had taken place before Anderson went to America with his two colleagues to investigate the use of machine tools in arms manufacture, showing that engineers in Britain were already aware of the economic benefits which accompanied an integrated design and manufacturing approach.

Design through competition

In August 1864, following the recommendations of the Committee on Breech Loading Arms, the War Office issued an advertisement inviting gun-makers and inventors to submit plans to convert the Enfield pattern 1853 from a muzzle to a breech-loader, calling for two main criteria to be met. The first was that the cost was "not to exceed £1 per arm" and the second was that "The shooting of the converted arm not be inferior to the Enfield rifle" (un-modified muzzle loader). .24. On completion of the modifications, the converted weapons were to be assessed for accuracy, penetration, initial velocity, recoil, rapidity of fire, liability to failure, simplicity of management, fouling and exposure to weather. Interestingly, the Committee had made no references which might have suggested that ease of manufacture or assembly was to be considered.

The advertisement attracted fifty different applicants for the conversion work. After careful examination of the submissions, the applicants were eventually whittled down to the following eight systems, these being "the most promising for the object in view:-

1. Storm's
2. Shepard's (b)
3. Westley Richards'
4. Wilson's
5. Green's
6. Snider's
7. Joslyn's
8. Shepard's (a)".

The first of the above five systems used the standard Enfield rifle cap and nipple method of igniting the charge, while the latter three had been adapted for cartridges carrying their own ignition. .25.

To make the trial absolutely fair, the Superintendent of the RSAF selected 48 rifles from stock and had them tested for "soundness and accuracy at 500 yards' range", before they were issued (six each) to the chosen competitors for conversion. Preceding the trial, all converted rifles were subject to the regulated proof to ensure the safety of the breech arrangement. Four rifles were selected from each individual six and assigned to experiments for range, accuracy, penetration, initial velocity and recoil. The remaining two rifles were reserved for further experiments concerning rapidity of fire, liability to failure, simplicity of management, fouling and exposure to weather. .26.

Over the coming months extensive trials were carried out. When it was reported that more than 5,500 rounds were fired with only one miss-fire, this allowed the Committee to conclude that the converted weapons "...are therefore much superior in this respect [mis-firing] to the muzzle-loading Enfield". This gave the Committee members the confidence to state that "the Committee feel justified in recommending that, for the armament of the infantry, the conversion of the Enfield rifle to a breech-loader on Mr. Snider's system may now be proceeded with to any extent which the Secretary of State may deem advisable". .27.

The final report by the Ordnance Select Committee on the 21st

June 1866 had resulted from an exclusive trial of the Snider converted breech loader against the Enfield muzzle loader. Here the opportunity had been taken to test the latest pattern cartridge proposed by Colonel Boxer, Superintendent of the Royal Laboratories at Woolwich. For the final experiment, which was to prove the most severe, the Committee arranged for two of the converted rifles to be fired ten times each, then plunged into "...brackish water, wholly immersing them, and allowing the barrels to become filled with water, one with a cartridge case in the barrel and one without". The rifles were then removed from the water, the barrels emptied out and the weapons laid on grass exposed to the weather. This experiment was repeated over four days and on the fifth day the rifles were examined. It was then discovered that on both samples the sliding cover of the spring of the breech block pin had rusted to such an extent that it prevented the mechanism from operating easily. The breech block had to be pressed back with the foot and as a consequence the two sections of the spring cover were forced together and the spring did not have the power to open them. In spite of this, it was reported that the rifles were still serviceable "and could be loaded with comparative ease". It was further reported that the accuracy of the rifles was affected during the firing of the first 25 rounds due to rust having formed within the barrels. However, after this short period of use the report notes that the rifles were "restored by firing to their original condition, the accuracy of the last six targets being equal to that with clean rifles". .28. It will have been noted from the reports of the exceedingly harsh testing that the overwhelming emphasis of the trial was to observe how well the weapon performed under extremes of battlefield conditions, not how easily it could be manufactured.

Further rigorous testing followed. A rifle was selected and laid on the ground with its breech closed, whereupon sand and dirt was thrown over the mechanism. After the debris had been shaken off and removed by hand, the rifle was reported to be "...at once perfectly serviceable". The experiment was repeated, this time with the breech open when it was reported "There was some difficulty in clearing the breech entirely by the hand alone, but by means of a small piece of stick picked off the ground the dirt was cleared out and the rifle was fired". After subjecting the rifle to further tests and carrying out a number of severe experiments with the "Boxer" ammunition which involved placing 20 cartridges prior to firing in a barrel of wet sawdust for periods of between 118 and 192 hours, the Committee came to the following conclusion:-

> ... that a considerable increase of accuracy by this system of conversion at all ranges; yet, in the opinion of the Committee, the precision at ranges beyond 700 yards is not such as will meet all the requirements of the service in the field, looking to the number of skilled marksmen in the ranks of the Army; and therefore the recommendation ... that the Superintendent, Royal Laboratory, and Superintendent, Small-arms Factories, should investigate the subject of small-bore breech-loader, of 0.45 or 0.50 calibre, adapted for ammunition carrying its own ignition, should still be carried out. .29.

The Committee in the final paragraph of their report were of the opinion that the trials of the Snider breech loading rifle proved so satisfactory that it had "at length enabled them to recommend to the Secretary of State for War, the immediate armament of the British Army (if so desired), a breech-loading weapon and an ammunition which in point of simplicity and general efficiency, they confidently believe will be found superior to any other with which any foreign army is provided".

.30. Apart from the converted Snider breech-loader (Fig.7) being the first weapon of its type to be manufactured in quantity at Enfield, it was the first weapon in Britain to be produced with a steel barrel in place of the traditional iron component. Although the Committee recommended that the Snider breech-loader go into service with the British Army, they had already voiced certain reservations over the weapon's "precision at ranges above 700 yards" and went on to suggest that the Superintendent at Enfield investigate the merits of a "small-bore breech-loader, of 0.45 or 0.50 calibre". This is clear evidence that, while the Committee recognised the battlefield merits of the Snider, by recommending this weapon they were accepting a compromise solution. Under the system of selection by open competition, it would be difficult, if not impossible, to arrive at anything better. It will be immediately recognised that the Committee's suggestion that Enfield should investigate the possibility of designing a weapon with a smaller calibre, would, if successful, release another arm requiring a different type of ammunition creating serious problems for the Army. It will be recalled that the issue of at least three weapon calibres had serious consequences for the Army at the Crimea.

By studying other reports issued by the Ordnance Select Committee there appears to be no evidence which would suggest that the War Office had ever considered laying down a detailed specification for a new weapon, by creating a development programme from scratch. Apart from the obvious benefits of ease of manufacture which would have resulted, the problems of having different calibres of ammunition could have also been avoided by careful design. However, contained within the trials of the different breech loading systems there is a considerable amount of information relating to experiments for accuracy, rapidity of fire, initial velocity, fouling and exposure to weather. It would, therefore, seem that the thinking of "Ordnance" was still heavily biassed towards battlefield needs and had yet to appreciate the savings to be made in production time, labour costs, material wastage and final product cost by integrating or linking the weapon design to the manufacturing process.

As mentioned above, the Committee, in its deliberations, had referred to the report written by George Lovell some 15 years earlier, in 1849, on the subject of the Prussian breech loading needle gun. This is perhaps an indication of the state of the technical progress within "Ordnance". Surely it can not be argued that the method of weapon development by a process of evolutionary change, as had been adopted by the War Office, (which by 1856 had taken over the responsibility of weapon procurement from "Ordnance") would be either faster or more efficient than a properly integrated design and manufacturing programme. Therefore, it would appear, from the adopted method of new weapon selection, that the War Office were no better at appreciating the range of benefits to be gained from an integrated design and manufacturing programme than their "Ordnance" predecessors. The compromise results obtained through weapon selection by open competition must surely have been predictable to the military, as at best, it only partially satisfied all the performance requirements of the small arm. On occasions there were disappointing outcomes to this method of selection when, after months of fatiguing trials, there was no weapon chosen at all. This would hardly seem the most efficient and cost effective way of equipping the armed forces with the latest in weapon technology. Clearly Government had yet to heed fully the wisdom of John Anderson when he spoke of making the weapon fit the machine. If War Office had understood the implications of Anderson's concepts, they would have appreciated that battles could often be won on the factory floor.

A deliberate design policy, perhaps?

One might speculate that "Ordnance", because of the Crimean War and the pressing need to supply small arms to the front line troops, had taken the quite deliberate decision to commit Enfield to producing the pattern 1853 rifle without concern for ease of manufacture. In fact, they would have had little choice, as the 1854 contracts placed with the Ames Company and Robbins & Lawrence had clearly specified jigs, fixtures and gauges only for this particular arm. The Enfield pattern 1853 was the latest British weapon of the day; its introduction into military service had coincided almost exactly with the American machine tool contract. Because of this, "Ordnance" would have had little option but to produce the rifle on the new manufacturing system. The pressing needs of the Crimean War would not have permitted the necessary changes to the design to improve ease of manufacture, even if this aspect had been fully appreciated. If design changes had taken place, there would have been a requirement to make subsequent alterations to the manufacturing processes. It would also have been necessary to alter or replace some of the jigs and gauges, resulting in unacceptable production delays.

Historically, the pattern 1853 had evolved out of trials ordered by Lord Hardinge in 1852, when five leading gun makers were requested to submit suitable samples of their weapons for experiment, alongside the Minie and a rifle designed by George Lovell. .31. It is clear from this method of weapon selection (a process of elimination by competition) that ease of manufacture and assembly was not a priority; in fact it was not part of the acceptance criteria. A decade after the introduction of the pattern 1853 it was agreed to proceed with a new generation of weapon, the Snider breech-loader. However, it should be recognised that this weapon was only a modified pattern 1853. Ironically, the Enfield factory coming on stream with its new system of mass production after cessation of hostilities in the Crimea had helped to increase dramatically the number of pattern 1853 rifles in circulation to over 800,000. Under the circumstances there would have been little likelihood of getting political agreement to lay down a programme for a new arm which could be manufactured more easily. Having 800,000 rifles with the potential of being converted to the next generation of arms technology at the unit cost of only one pound would no doubt have provided a powerful incentive to ignore the potential benefits of a system based on ease of manufacture. It was the success of the

"American system" at Enfield which greatly increased manufacturing output, coupled with the pressure placed upon the private sector to produce arms for the Crimea, which had boosted the number of the pattern 1853s in military possession at the end of the war. This had provided the most likely reason for delaying, or more accurately halting, progress towards a fully integrated weapon design and manufacturing programme. The weapon design policy, which was really no more than arms by selection, can therefore be viewed as having been forced upon the authorities by a chain of circumstances over which they had little control. This situation can be seen as resulting in the military being denied their ideal small arm for battlefield performance, as the outcome of such a scheme must inevitably lead to a compromise choice.

The first glimmer of understanding

One of the first indications that ease of weapon manufacture was about to be considered came when an invitation was posted in October 1866 for an open competition between small arms makers and designers. The "programme of experiments", as specified within the official War Office advertisement for weapon submissions, contained a list of the nine performance headings. Here accuracy was listed first and manufacture last. The word manufacture also appeared within the concluding report of the Special Sub-Committee on Breech-Loading Arms, dated 12th February 1868, almost as an afterthought. Little can be learned from this document of precisely what the Committee had in mind with regard to manufacture.

The nine weapons under scrutiny had been passed to Colonel Dixon, the Superintendent of the RSAF, who had estimated the cost of their separate manufacture. However, a most revealing piece of information of how manufacturing requirements were regarded comes to light when the Committee reported that it was unable to publish details of Dixon's costs as it was "not required by the terms of the War Office Advertisement". In spite of these reservations, it would appear that Dixon's advice had been somewhat influential, as there is the suggestion that ease of manufacture was about to be taken seriously. The Committee in their assessment of the weapons were prepared to write:-

> "...the Sub-Committee decided on placing the competitive rifles in the following order of merit, with regard to their facility of manufacture in quantity and uniform quality, those which are bracketed together being considered equal":-
>
> Burton, II
> Joslyn
> {Henry
> {Albini and Braendlin
> {Martini
> Fosbery
> Peabody
> Remington
> Burton, I

When the Sub-Committee came, in their conclusion, to place the weapons in merit order after completing the general trial experiments, their positions had changed to the following:-

Henry
Burton, II
Albini and Braendlin
Fosbery
Burton, I
Peabody
Martini
Remington
Joslyn

Unfortunately it is not possible to deduce from the report whether "manufacture in quantity and uniform quality" had been taken into account in the final placing as there is no reference to the word manufacture under the heading "Conclusion".

As none of the individual arms had met all the requirements laid down in the War Office advertisement, it was stated that "the Sub-Committee do not feel justified in recommending the Secretary of State for War to overlook the want of compliance with the qualifications and award the £1,000". The Sub-Committee then went on to suggest that disqualification from the £1,000 prize should not preclude eligibility for the £600 prize for breech mechanisms. They believed that "the following rifles, having attained a satisfactory degree of excellence in other particulars, are eligible for this prize, and place them in their respective order of merit":-

Henry
Burton, II
Albini and Braendlin
Burton, I

The report finally ends with the conclusion that the "Sub-Committee cannot refrain from expressing their regret that no arm submitted to them should have shown sufficient merit to render its introduction into the service advisable". Although they did go on to say "the present service arm performed well during several of the trials to which it was subjected, and proved itself in many respects an efficient military weapon".

.32. In effect, fifteen months had been spent, perhaps wasted, from the time of posting the advertisement to the conclusion of the report, only to confirm that the Snider breech loader was "an efficient military weapon".

This report, which is not untypical of others dealing with weapon assessment, illustrates quite clearly the difficulties with the system of open competition. Once again it can be observed that different weapons, because of their individual characteristics, are apt to perform differently from each other in separate categories of test. Under such a system of selection it would be virtually impossible to get one type of weapon to be outstanding in every aspect of the experiment. The episode highlights a serious flaw in the weapon selection system, which is that, by its very nature, it can not guarantee that at the end of a trial the military will have an improved specification weapon. Even if a weapon is finally chosen after this long period of assessment, there could still be serious consequences for national security. The business of constructing jigs, tools and fixtures can not begin until the weapon is finally chosen, adding considerably to the length of the overall development programme.

A change in the selection procedure

Throughout the remaining period of the 19th century the progress of military weapon development relied almost exclusively upon the designs of private companies and individuals. After much deliberation between the War Office Committee, arms experts and leading gun-makers, it was eventually decided to separate the evaluation of barrels from evaluation of breech mechanisms. Rifled barrels of Henry, Lancaster, Rigby, Westley-Richards, Whitworth and Enfield, judged previously as giving the best results, were selected for competition. Limits were set for length, weight, barrel calibre and type of cartridge. After extensive tests the Committee reported that they had selected a barrel from Alexander Henry of Edinburgh, Scotland and a breech mechanism designed in Switzerland by Frederich von Martini. These two components were to be incorporated into a single weapon by workmen at the RSAF, the arm becoming known as the Martini-Henry (Fig.8). Here it was hoped that the initiative would create "a model long-range arm of precision". .33. However, there was still no suggestion that the method of evaluating separate components of the rifle had been adopted to take into account ease of manufacture. From the documentary evidence it is clear that the main objective was still centred on improving the weapon's battlefield performance which had been achieved by marrying together the best breech and barrel. This new method of selection would seem to confirm that the War Office Committee had finally come to recognise that the inevitable performance compromise experienced in the past, through the choice of a single weapon by competition, could at least be ameliorated by selecting the best features of more than one gun. Also, there was the advantage that the tooling-up time for the "amalgamated weapon" could be less than the previous arm. The fact that the Martini-Henry was constructed from "off the shelf" parts would have meant that patterns, jigs and gauges were already available for copying.

Experiments to evaluate separate gun components were to become the norm, throughout the development of the magazine rifle with the introduction in 1891 of the bolt action Lee Metford Magazine Rifle Mark 1 (Fig.9) followed in November 1895, by the now famous bolt action Lee Enfield Rifle Mark 1 (Fig.10). By the time the Lee Metford went into production, there was still no evidence to suggest that ease or economy of manufacture was being seriously considered. For example, the weapon was constructed from 82 separate component parts including screws and pins which took 950 different machines to produce them. There were some 1,591 production processes and, with the inclusion of accessories, the figure increases by 17% to 1,863. .34. The metal components of this weapon consisted mainly of steel, with just two made from iron, while brass was used only for the heel plate screws and those to secure the regimental number plate. In a lecture given to the Institute of Civil Engineers in November 1892, the then Superintendent of the RSAF Enfield, John Rigby, listed the following material processes in the manufacture of the Lee Metford rifle:-

> steel-analysing, testing, forging, rolling, stamping, annealing, drilling, boring, tapping and screwing, milling, turning shaping, slotting, drifting, brazing, soldering, grinding, filing, polishing, hardening and tempering, bluing and browning; as to iron-forging, turning, filing, screwing and case hardening; as to brass-casting, rolling, drawing, filing, turning, punching, screw cutting and polishing; as to wood-seasoning, turning, machining, boring, filing, oiling and polishing. .35.

Comparing the magazine Lee Metford to the earlier and simpler muzzle loading Enfield pattern 1853, it will be noted that the latter took approximately 680 machines and 719 different operations and processes to produce the 61 parts of this weapon. .36. From the two sets of production figures it will readily be observed that the average number of machines required to produce a single part remains similar at just over 11. However, it will be noted that the average figure for processes per part has increased dramatically from 11.8 for the pattern 1853 to 19.4

for the Lee Metford, an increase of over 39%. This comparison suggests that, as the complexity of the weapon increased, there had not been any serious attempt to simplify or reduce the number of manufacturing operations. Given the improved level of manufacturing technology in existence as the 19th century drew to a close, compared to the labour intensive methods employed prior to the "American system" being installed at Enfield, it would seem, particularly with the benefit of 20th century hindsight, that the War Office policy of weapon selection by competition rather than through the issue of a design brief, meant that a golden opportunity to reduce the cost of plant, equipment, measurement and inspection had been missed.

Examining a cocktail of complexities and probabilities

In this chapter it has not been possible, through lack of substantive information, to look comprehensively through the eyes of 19th century "Ordnance" observers to analyse, from their perspective, how they saw the relationship between weapon design and ease of manufacture. To date, John Anderson has been the only credible "Ordnance" employee found who has firmly grasped these engineering concepts. Therefore, the opportunity will be taken to introduce some possible scenarios for "Ordnance", based upon 19th century evidence while relying on 20th century experience.

To avoid future difficulties and to ensure maximum economic benefit as manufacturing methods advance and weapons become more complex in specification, it would have been necessary for any factory management to review the capabilities of their machinery, their production processes and work-force skills before a new product was introduced. In the 20th century these problems would tend to be addressed by integrating product design with the manufacturing process. One way to achieve this would be to establish a post-development team of engineers at the manufacturing site to act in a liaison capacity between the shop-floor and the original design team. Experience has shown that, without a policy or a co-ordinated strategy which takes into account all the manufacturing and design aspects of a product, a factory will inevitably suffer from poor quality and delays. This will result in loss of manufacturing output and as a consequence a more expensive product. In the case of a private sector company in a competitive business environment, a loss of market share could result.

One might speculate as to why the War Office did not, as the 19th century progressed, introduce or consider a co-ordinated design, development and production programme for weapon manufacture. This might have saved the Exchequer a considerable amount of money. Was it because "Ordnance" procurement and manufacture was controlled by military bureaucrats who were only interested in how the weapon performed, not in how it was made? Perhaps it was due to the fact that the Enfield factory was effectively under Government control. Traditionally, such establishments have been hampered in their operations by the complexities of the decision making process which is linked to Parliament through committees and Civil Servants. This prevents speed of decision making and compromises flexibility, which in turn can reduce the expected benefits derived from an economy of scale. It is known that smaller, leaner companies are often more responsive to market need, particularly if they have observed a large competitor go to the expense of pioneering a new product or process. One might cite the Birmingham Small Arms Company as a case in point. Unlike the RSAF at Enfield, they did not at first establish all manufacturing operations under one roof. In the early years of operation not only did they employ both machine and manual methods of gun manufacture they also put work out to local barrel makers. Presumably this was to help reduce initial set-up costs. The "spin off" effect from this would help to spread the load of the work in progress, thereby helping to cushion a rapid decline of skilled workmen within the area. .37. In 1865, a correspondent writing in The Engineer said of BSA that it not only had the advantage of having "...only to step into Staffordshire for its iron and it commands the best market for its stocks", but also that "...conducting its business through businessmen, who cannot afford to manufacture at a loss, it possesses one other advantage which Government does not". .38. This 19th century notion of government manufacturing establishments not being particularly efficient and cost effective has been maintained either rightly or wrongly by many right up to the present day.

The lack of an integrated design and manufacturing policy may also have been a hang-over from the days of the old contract system. Under this regime Government had to appease the private gun trade by allowing the bulk of the small arms work to go to them. However, in one respect this was a benefit for Government, as it allowed "Ordnance" to defray production costs by the arrangement of out-work, thereby keeping down expenditure on capital equipment and labour. Having such a manufacturing system in existence would have lent itself more readily to military weapon selection by open competition, albeit that the performance of the weapon eventually chosen was a compromise. In the short term, this method of selection might have appeared attractive to those controlling the Government purse strings being less costly than employing an internal weapon design team.

Government could be forgiven if it had taken the view that the technology of the standard soldier's firearm was reaching its zenith by the final quarter of the century and development was, as a consequence, slowing down. Therefore, from a Government perspective it might have seemed that there was little benefit to be gained from the expense of establishing an in-house design team, had this particular aspect been recognised. The slowing down process can be identified most dramatically in the design of the Lee Enfield rifle. This weapon continued in British military service from the 1890s through over six decades which included two World Wars, with little alteration to the basic design.

It might be further argued that in the 19th century, only a private company free of bureaucratic control could effectively achieve an integrated programme of product design linked to an efficient method of production. Ideally, such a company would require the capability to design, although not necessarily to construct, both the product and the machine tools to produce it. Such a company would have required the confidence and financial security of long term contracts and it was usually only government who could provide the necessary support in terms of scale. From the evidence available, it would seem that the British Government would not have been prepared to invest in such a venture, as it was content to rely mainly upon its own in-house and contractor manufacturing, while allowing weapon development to evolve through the method of open competition, trial and experiment. To date, research has only uncovered a small number of references in official documents to considerations of ease of manufacture. Occasionally a rejection is witnessed on grounds of expense and possible difficulties in producing the weapon. This happened in the case of the Owen Jones rifle during the initial technical evaluation trials in 1882 but remains a fairly isolated case. .39

John Anderson, the highly regarded "Ordnance" engineer, when giving evidence before the 1854 Select Committee on Small Arms, responded to the following question:- "You are of the opinion therefore that every part of a musket is so simple as to be capable of being produced by machinery?", thus:-

> Yes. I should mention that there are some of the present parts that have an irregular form, which have nothing to do with the musket, as a musket, neither with its accuracy or its quality, and that many of these, if I had anything to do with the getting up of the manufactory, I would prefer that they were altered in form; simplified and made more chaste in appearance, and not so crooked as some things are without any necessity. .40

The conclusions drawn by Anderson relating to weapon design for ease of manufacture, shortly before the installation of the American machine tools at Enfield would tend to support the theory that at least there was an early recognition in Britain of these issues by people with manufacturing backgrounds. At first this might suggest that Anderson's opinions had either been forgotten, or deliberately ignored. However, it is more likely that his views were overridden by the many complex factors, some historic, which existed just prior to the Crimean War, which led to expediency determining the outcome for "Ordnance".

Had Anderson's views been implemented, this would have meant "Ordnance" committing resources to employing weapon designers. These men would have had to be proficient in understanding the requirements of the latest machine tools or, at least, be engineers capable of writing detailed weapon specifications which were easy for manufacturers to comprehend and suited to contract by tender. With war looming and pressure on "Ordnance" to fully mechanise its manufacturing operation at Enfield, it was unlikely that options to improve weapon design to aid ease of manufacture would have been given high priority. As we have seen, Britain's entry into the Crimean War late in March 1854 coincided almost exactly with the decision to equip Enfield with the latest American machine tools, although the decision came too late for the Army to benefit from the eventual increase in weapon production. Given the state of weapon supplies at the start of the Russian conflict, it would have been irresponsible of "Ordnance" to have tampered with the design of the pattern 1853. Design changes to the pattern 1853 would have meant new sets of gauges to accommodate the simplified part profiles envisaged by Anderson. This would have led in turn to changes in inspection procedures. Not only would there have been serious consequences for future manufacturing output at Enfield had things gone wrong but "Ordnance" would also have risked causing delays to the production of arms supplied by the private contractors (a major source), as it would have taken time to prepare new jigs and gauges for the private sector. As a consequence the front line troops at the Crimea would have been seriously prejudiced.

However, it is probably fair to conclude that the argument for leaving the design of the weapon unaltered, so as not to cause production or supply difficulties, was not generally understood by senior members of the Board of Ordnance. Chapter Eight provided a considerable amount of evidence extracted from correspondence between Captain Dixon, Superintendent of the RSAF and Viscount Hardinge (who during the Crimean conflict had been appointed General Commander in Chief of the Forces) over the latter's wish to introduce new types of arm regardless of the complexities of manufacturing and tooling-up time-scales. A further reason for the pattern 1853 remaining unaltered was that in 1852, Hardinge, then Master General of Ordnance, had been responsible for instituting a competition between small arms inventors which had led to the development of this weapon. Once this weapon had gone into production, it would have been unlikely that Hardinge would have risked a further period of experimentation with what had become the accepted service weapon. This would have been a particularly sensitive and unsettling time as the pattern 1853 had just succeeded the short lived Minie, introduced by his predecessor the Marquis of Anglesea. .41.

There was a further important ingredient which should not be overlooked as it would have provided a distinct disincentive to making the pattern 1853 easier to manufacture. After the death of the Duke of Wellington in 1852, it was Hardinge's decision that was ultimately responsible, through the introduction of the pattern 1853, for reducing the calibre of the standard military weapon to 0.577 inch. This decision could have proved a potential strategic disaster for the Army. Previously British calibres tended to be in excess of 0.7 inch, as Wellington had advocated that "the English musket-ball should not be altered as a principle". He was of the opinion that the heavier calibre ball would break a horse's leg, while a lighter ball would only wound and not cripple the animal. .42. Wellington's view was probably a throw-back from earlier wars when the use of cavalry was quite extensive. Bringing down a horse with its armed rider was an important and strategic part of warfare. As the sophistication of weapons improved, with increased range, rapidity of fire, and accuracy, the use of cavalry became less important and would eventually become obsolete. However, Hardinge could not have been absolutely sure, in the middle of the 19th century that the introduction of the smaller calibre would bring about the advantages envisaged and the decision on his part to accept the design was probably a calculated gamble. Even if he had understood the manufacturing advantages to be gained from design modifications to the arm, it is doubtful if he would have risked further changes.

Anderson has a 20th century supporter

It is interesting to observe that the earlier views of John Anderson regarding ease of weapon manufacture are supported almost eighty years later by the Superintendent of the RSAF, G H Roberts. When writing the history of the factory in the early

1930s, Roberts, although fully acknowledging Anderson's self confessed lack of expertise concerning the ballistic science of small arms, is nevertheless sympathetic to his views on how a weapon might be designed to improve its ability to be manufactured, when he comments:-

> ...as an Engineer and Mechanic he [Anderson] was of the opinion that the designs might be very much simplified so as to make them easier and cheaper for manufacture without in any way interfering with the efficiency of the weapon - a line of argument which has had to be again used by the present writer and his staff during the last few years. .43.

It would seem from the results of research presented above and also by the general lack of documentary evidence concerning ease of manufacture, particularly at times when new weapons were being evaluated, that this feature was given a low priority on the "Ordnance" scale of desirability. From the comments expressed by Roberts, it would seem that this state of affairs persisted well into the first part of the 20th century. Further research would be required, which is beyond the scope of this thesis, to confirm how widespread the lack of integrated design and manufacturing really was.

Because the Lee Enfield magazine rifle (in slightly modified form) stayed so long with the British Army, it would be interesting to discover through a future project if small arms selection had been reduced to no more than refining the standard service weapon. If this proved to be the case, then 19th century selection methods would have indelibly stamped their mark on the future of military arms procurement. It would seem clear from the above evidence that the main objective for 19th century selectors of British military arms was to ensure that the weapon chosen performed well in all aspects of battlefield conditions and was therefore capable of eliminating the enemy. Of course it was important for selectors to ensure unit costs of small arms were kept to a minimum but the predominant criteria for selection was how the weapon performed overall. If it could be manufactured easily and cheaply then this was a bonus.

From the evidence before us, one must conclude that, influenced by the method of weapon selection, which had evolved in parallel with the contract system, it was military battlefield performance which took precedence over best engineering practice in weapon design and manufacture. These were the ingredients which were responsible for delaying advances in weapon design and manufacturing technology in Britain.

NOTES

.1. House of Lords Record Office, Select Committee on Small Arms, 1854, evidence of John Anderson, p.75

.2. Public Record Office, Kew, Correspondence from James Aston to Master General of the School of Musketry, 21/1/1885, and letter from Harrison Trent to the Secretary of State for War, 12/1/1885. Reference Supply 5/887

.3. Blackmore, Howard L, British Military Firearms (1650-1850) (London 1961), p.227

.4. Ministry of Defence Pattern Room, Nottingham. Notes on The History Of The Royal Small Arms Factory, Enfield Lock. Unsigned typed manuscript c1930, accompanied by a memorandum, dated 24/12/30, signed, G H Roberts, (Superintendent RSAF 1922-1931), clearly showing that he was the author of the RSAF history. p.C12

.5. House of Lords Record Office, London. Proceedings of the Committee Appointed by the Secretary of State for War, June 1864. Reference, Accounts and Papers 1864 XXXV, p.302

.6. Ibid., pp.297 & 302

.7. Ibid., pp.297 & 302

.8. Ibid., pp.297 & 302

.9. Ibid., p.298

.10. Ibid., p.298

.11. Ibid., p.298

.12. Ibid., p.299

.13. Ibid., pp.299-300

.14. Ibid., p.301

.15. Op.cit., Roberts, p.C.14

.16. House of Lords Record Office, London. Subject: On the Conversion of the Enfield Rifle to a Breech-Loader. 6 February 1865. Reference, Accounts and Papers 1865 XXX11, p.355

.17. Dictionary of National Biography, Smith Elder & Co. London 1908.

.18. Skentebery, Norman, Arrows to Atom Bombs, a History of the Ordnance Board, HMSO 1975, pp.12-14

.19. Smith, Merritt Roe, Harpers Ferry Armoury and the New Technology, Cornell University Press, (London 1977) pp.219 & 249

.20. Ibid., p.249

.21. Ibid., p.250

.22. Putnam, Tim & Weinbren, Dan, A Short History of the Royal Small Arms Factory Enfield, Middlesex University, (Enfield 1992), p.38
In conversation Professor Putnam has put forward an interesting point of view, suggesting that mechanised advances in American small arms manufacture had chiefly derived benefit from its workmen, who unlike their British counterparts, had no big gun industry to distract them.

.23. Op.cit., Select Committee on Small Arms, 1854, evidence of John Anderson, pp.74-76

.24. Op.cit., On the Conversion of the Enfield Rifle to a Breech-Loader, p.355

.25. Ibid., p.356

.26. Ibid., pp.356-360

.27. House of Lords Record Office, London.
Subject: Mr Snider's Method of Converting the Enfield to a Breech-loader. June 1866. Reference, Accounts and Papers 1866 XL1, p.403

.28. Ibid., p.406

.29. Ibid., p.406-407

.30. Ibid., p.408

.31. Ibid., p.408

.32. House of Lords Record Office, London.
Subject: The Trials of nine descriptions of Breech-loading Rifles accepted for competition in accordance with the terms of the War Office Advertisement of 22/10/66. Reference, Reports Commissioners 1866-68, XV1, pp.32-34

.33. Reynolds, E G B, "Enfield Arms, the early Breech-Loaders", Small Arms Profile, No.18, pp.103-117

.34. Rigby, John, "The Manufacture of Small Arms", Section.1, Minutes of Proceedings, The Institute of Civil Engineers, 29 November, 1892, p.11

.35. Ibid., pp.10-11

.36. "The Royal Small-Arm Manufactory, Enfield", The Engineer, March 25 1859, p.204. Also see "Leviathan Workshops No.11 The Enfield Small Arms Factory", The Mechanics Magazine, September 6 1861, p.145. Referring to the RSAF during production of the long pattern 1853 Enfield, it is suggested that "...upwards of 800 machines and approaching 2000 hands - young and old are employed. 350 finished rifles per day is the maximum rate of production; and upon each rifle there are expended nearly 800 separate processes of manipulation".

.37. Lumley, Roger, "The American System of Manufactures in Birmingham: Production Methods at the Birmingham Small Arms Co. in the Nineteenth Century", Business History, Vol.31, 1989, pp.30-31

.38. The Engineer, Vol.19, April 14, 1865, "Gun Making by Machinery, The Small Heath Factory", p.224

.39. Op.cit., Reynolds, pp.114-115

.40. House of Lords Record Office, Select Committee on Small Arms, 1854, evidence of John Anderson, p.29

.41. Ministry of Defence, Pattern Room, Nottingham, Report of Experiments With Small Arms, Carried on at The Royal Manufactory, Enfield. 1852.

.42. House of Lords Record Office, The Committees Army and Ordnance Expenditure Session, 1st Feb - 1st Aug, 1949. Vol.9, pp.305-307

.43. Op.cit., Roberts, p.C6

19TH CENTURY TECHNOLOGICAL DIFFUSION AND THE INITIATING FORCES

The term diffusion or transmission "(employed interchangeably)" as broadly defined by David J Jeremy means "the spread of an innovation from its originating firm or economy to a host firm or economy". Technology is defined as "a spectrum, with ideas at one end and techniques and things at the other, with design as a middle term." .1.

Research for this thesis has shown a number of ways in which technology was transferred, diffused, "borrowed" or deliberately stolen and sometimes sent or passed on by artisans and others. These mechanisms were not just confined to the transfer of skills and know-how within and between companies in a limited area but also extended to transfer overseas. Often knowledge and techniques would be passed through a network of emigrating craftsmen to the new country, who by simply starting work elsewhere, without a thought for industrial espionage, had automatically transferred their skills and knowledge. In the new country it was possible for the emigrant's knowledge to be diffused throughout the host company, but prior to this taking place, the knowledge could be added to and enhanced by the indigenous workforce through artisans working together before being passed on. This particular phenomenon can be traced through similarities in the design of certain machine tools and other products which occurred in different parts of the world almost simultaneously, as if by magic. For example, the early 19th century machine tool development within the American National Armouries, which was linked to standardisation and interchangeable parts, can be traced to ideas which had originated in 18th century France. Here one suggested link was the American Ambassador to France, Thomas Jefferson, who was himself an inventor. It was Jefferson who drew the American Authoritie's attention of Honoré Le Blanc's ideas for the precision manufacture of gun locks. Although the system was not taken up immediately by the U.S. Ordnance Department, Merrit Roe Smith has suggested that it was likely that Eli Whitney drew inspiration from Le Blanc's work when making a bid for his first Government arms contract. .2. Eventually these ideas and techniques, which were encouraged and supported by the U.S. Government, evolved into the process of precision manufacturing which was to become widely known as the "American system of manufactures".

While there is evidence to suggest that particular ideas were diffused in a reasonably precise and structured way, there is also the suggestion that a certain amount of diffusion occurred more haphazardly, in some instances by accident but more probably through natural causes by workers merely being together. Although it might be suggested that definitive evidence is lacking to support this latter premise, it would seem unreasonable to assume that certain artisans did not bring or take their particular skills and knowledge to other companies when transferring employment. Craftsmen are often needed urgently for their particular expertise and it would have been logical for friends and internal contacts in other companies who knew the individual skills of a workman to inform him that a job vacancy existed. This type of informal communication is quite prevalent among groups of skilled and unskilled workers and can be identified today. The practice is often referred to as "networking" .

Immigrants and the internal and external diffusion of skill

When researching the documentation relating to the technological developments within the small arms industry on both sides of the Atlantic, one often discovers references to personnel either visiting or working within an equivalent establishment to that of their home country. It can not always be discovered whether these people were employed in exactly the same branch of their trade, although it can usually be determined that they worked within a similar establishment. However, we are fortunate that George Lovell, when Storekeeper at Enfield Lock, recorded in his own hand a number of helpful comments. These are contained on fly sheets inter-dispersed within an anonymously written document, published in 1829, entitled "Observations on the Manufacture of Fire-Arms". Here Lovell has been able to personally chronicle for us this early example of technological diffusion:-

> The following is a list of Artificers emigrated from this Country who were ascertained to be employed in the United States Government manufactories: - as copies from a Document forwarded to Sir H Hardinge on the 18 May 1826.
>
> At Springfield
>
> Samuel Collins Sen :} Barrel Forgers.- There are upwards of
> Samuel Collins Junr:} 50 British Artificers at work in this establishment but their names are not ascertained.
>
> At Harpers Ferry
>
> John Chapman }
> Joseph Chapman}
> James Russell } Barrel Forgers
> Thomas Russell}
> Mark Freeman } .3.

This early evidence of the diffusion of skilled immigrant workers is confirmed by Charles Fitch in his 1882 census. When discussing the year 1819 he states:-

> The division of labor at the time was also very different. So far as machinery had been introduced, its construction was rude, and its use exceptional. Hand-shaving and chiseling [sic] for the stocks, and hand-forging, grinding, and hand-filing for the metal parts, constituted nearly all the work. The filers - skilled workmen - were then mostly foreigners, and consumption of files was enormous. .4.

It is quite likely that these early examples given by Lovell and Fitch were emigrants from Britain and Europe, forced to cross the Atlantic to seek work, probably due to the reduced need for arms in the relatively peaceful years after the Napoleonic wars.

Although emigrants are not mentioned, Merrit Roe Smith has identified the considerable cooperation between the armouries of Harpers Ferry and Springfield, encouraged by their respective Superintendents, Stubberfield and Lee. This no doubt helped to quicken the pace of technological diffusion within America. Between the years 1816 and 1829 (the period identified by Lovell as having emigrants in both armouries),Roe Smith suggests that "borrowing" and "lending" of workmen took place between the two establishments. .5. This emphasises the likelihood of ideas, skills and know-how being diffused and shared, showing that mechanisms were in place to make it possible for British and European knowledge to be passed on, even in the event of emigrants not physically transferring between the two armouries.

The sharing of knowledge and ideas with their new work-mates, whether deliberate or by natural diffusion, would form part of the overall pattern of technology transfer which is sometimes difficult to identify and separate from its origins. Through the movement of workers between plants, the transfer of knowledge can take place almost like the spreading of a virus. In such circumstances it is not always possible to identify the original carrier and the mode of transfer can become lost.

Towards the middle of the century, after considerable research and development by American engineers into the technology of interchangeability, quite senior figures like James Henry Burton, the former Master Armourer at Harpers Ferry, crossed the Atlantic to assist with the installation and setting up of the new machinery supplied by Robbins & Lawrence and the Ames Company for the Royal Small Arms Factory at Enfield Lock. .6. Interestingly, Burton had been interviewed for the job at the Springfield National Armoury in 1854 when the British Commission visited on their fact finding tour. .7. This further supports the notion that technological diffusion within the United States was well established at the time and suggests that the American Government was less concerned than the British authorities about knowledge exchange. It was probably realised that, if you wished to export a complete production system based on new machine tools, it was inevitable that the know-how must be shipped as well.

Ormel Clark from Springfield joined the RSAF Stocking Department in 1856 and a fellow countryman, Mr Caulnin, came to work in the Smithy. .8. About the same time an English gauge maker, a Mr McGee, left Springfield to return to Enfield. An official report concerning the manufacture of small arms published in 1887 refers to an interview with McGee and confirmed that "a year and a half had been spent in the gun factories of America". .9. "Ordnance" gained further skills and experience for the new Enfield machine room by recruiting workers from Colonel Colt's London pistol factory for supervisory and machine-setting jobs. .10.

Further evidence of immigrant involvement in the British small arms industry can be observed after the establishment of the Birmingham Small Arms Company (BSA), when Corey M McFarland was appointed chief engineer in January 1862. McFarland had previously worked for the Ames Manufacturing Company in Massachussetts before coming to England to work at the London Armoury Company. Probably acting on personal knowledge, McFarland hired three experienced mechanics from America who joined BSA as supervisors. These men stayed at their posts for approximately three and a half years. In 1865 when BSA was unable to recruit skilled barrel setters locally, the company turned to Belgium for these workmen, thereby enhancing the transfer of international knowledge. .11.

Of course it was not only the immigrants who brought about diffusion of skills and knowledge. Sometimes indigenous workers were recruited or transferred naturally to other companies, dispersing their own expertise or authority within their new environment. BSA's first manager, Mr B McKay, came from the famous engineering firm of Whitworth & Company. George Vernun, previously with the RSAF at Enfield, was engaged by BSA in February 1864 as machine shop foreman. In the same year James Smiles joined BSA from the London Armoury Company and was engaged as head viewer. The former Superintendent of the RSAF (1855-1871) and managing director of the National Arms and Ammunition Company (1872-1874), Major General Manley Dixon, was appointed manager and company secretary to BSA in March 1875. In 1894 when BSA adopted the Enfield method of barrel browning, the RSAF's foreman browner was recruited. .12.

During the first part of the 19th century the Enfield factory, under the control of the Board of Ordnance, had been able to transfer workers from the Tower of London and Lewisham when the demise of these establishments as arms producers came about. In the second half of the century Birmingham, being the recognized centre of the British gun trade, had a whole range of skilled metal-workers at its disposal from its diverse industrial base. These artisans were able to provide a potential pool of experienced labour for the new BSA factory when it was established in 1861. Workers possessing metalworking skills would have been a more attractive proposition for machine intensive work than those from a non industrial background. Evidence from Colonel Colt and James Nasmyth, debated in earlier chapters, suggested that almost any intelligent man could be taken off the street and turned into a competent machine operator but the opposite view is that time and money could be saved by employing experienced workmen. By adopting this policy there would be a reduced training requirement, thereby allowing a faster integration of workers into the production process. It is not difficult to understand why BSA had a different attitude towards the employment of skilled artisans when the backgrounds of the men who came together to form the Company are remembered. These men have been classified by Roger Lumley as having "a craft mentality". .13. Given the growing pressure for different types of machine skills, brought about by industrial change as the century progressed, it is not difficult to imagine how it was possible for technological diffusion to take place. In fact, the evidence suggests that it would have been almost impossible for technological diffusion not to have taken place.

<u>Diffusion through competition, cooperation and evolution</u>

The system of selection by open competition used by "Ordnance" in the development of new and improved types of weapons should not be overlooked in terms of technical diffusion. Apart from the contribution made by the many indigenous inventors and gun-smiths to this method of small arms improvement, much influence in weapon design came from overseas through such people as Martini, Lee and Snider. A particularly good example, although strictly not to do with competition, can be seen in a letter dated 7th June 1866 to the British Under Secretary of State for War from Jacob Snider. Snider had requested the conversion of three Springfield rifles to the "Snider breech loading principle" by Enfield, as samples for the Egyptian Government. In making the arrangement, Snider had stated that no royalty payments would be incurred provided Enfield followed his instructions and stuck strictly to his drawing. Snider also stated that he wished to approve the modifications himself when complete. However, Colonel Dixon, the Superintendent at Enfield Lock, had remarked in correspondence that it was not possible to make the changes ordered by Snider without additional alteration. In further correspondence to the Under Secretary of State for War, dated

30th June, Snider stated that he had "...held consultations with Colonel Dixon". From this it can be deduced that Snider was reasonably satisfied with Dixon's recommendations, although he still stressed "When said arms are converted I shall expect them to be submitted for my inspection and approval before delivery to the Egyptian Government". Interestingly, Dixon had written on the back of the letter confirming that Snider seemed satisfied but remarked in relation to the Springfield rifle conversions "as the question is one purely of manufacture, I did not ask for Mr Snider's assistance in that point". .14.

By examining this particular piece of correspondence, we are permitted to experience how far-reaching and interrelated technological diffusion could really be. Here we have Snider the American inventor of a particular method of breech loading, discussing with Dixon, a British "Ordnance" Superintendent, the specifications for converting a rifle designed at the Springfield American National Armoury for eventual modification and supply to the Egyptian Government. This quite significant illustration has demonstrated how it is possible for ideas to spread almost halfway around the world from a single project. However, in making such observations and taking into account the style of the lock on several pattern 1853 Enfield conversions by Snider, a much earlier technical contribution had already been made. It will be recalled from our earlier discussions that the shape of the Springfield lock plate was similar to that of the pattern 1853 Enfield and both of these components had been influenced by 17th century French gun-lock designers. This particular aspect should not be neglected as it demonstrates that technological diffusion has accompanied the development of small arms along a several hundred year evolutionary path.

Famous people and famous companies

On both sides of the Atlantic there have been several examples of skilled engineers and craftsmen leaving the employ of a company with a household name to set up in business on their own account, eventually becoming household names in their own right. The Reverend Forsyth, famous in 1807 for revolutionising the development of firearms with his patent for the ignition of gunpowder by the application of fulminate, opened a gun shop at 10, Piccadilly, London with James Brougham. James Vicars, who at the time was chief mechanic at the Tower of London, was recruited to take charge of the new venture and James Purdy was appointed as stocker and filer. Joseph Manton, who had a gun shop at 314-315, Oxford Street, London had employed in his time the services of Charles Lancaster, Moore, Lang of Andover and Thomas Boss, all of them eventually leaving to set up on their own account. James Purdy (the company is still famous today for quality sporting guns) opened his first shop at 4, Princes Street, London, in 1814 and employed Thomas Boss between 1817 and 1821. Boss who had previously worked for Joseph Manton, had learned his trade from his father. Upon leaving Purdy, Boss set up his new business at 3, Grosvenor Street, London. .15. Just looking at this relatively small sample of famous London gun-makers clearly demonstrates how incestuous the trade really was and further helps explain how diffusion of skills and ideas took place. A cursory glance at the lists of 18th and 19th century gun manufacturers and related trades in both the Birmingham and London districts will quickly establish the more than coincidental connections between and within several firms. Here, clear links can be observed between certain companies through similarities in family name, trading title and partnerships. These connections demonstrate the retention of traditional craft skills by individual gun making families which were diffused through the generations which followed. On occasion, these skills would be shared with privileged workmen or, once learned, could be transferred as the craftsman changed employment.

Like the famous gun-makers, a similar pattern of cross-fertilization is evident among the engineers and machine tool inventors, developers and builders. Probably one of the most remarkable periods of eminent British engineering diffusion began with an invitation from Joseph Bramah to Henry Maudslay to join his lock manufacturing company in 1788. This was to help resolve problems of standardisation in production. Maudslay, who had previously been employed at the Woolwich dockyard, left Bramah after working with him for nine years. After his departure in 1797, Maudslay set up on his own account, the company eventually becoming the firm of Maudslay, Sons & Field. Joshua Field who had come to work for Maudslay in 1804, had formally been employed as a draughtsman at the Portsmouth Dockyard. .16. The diffusion knot had become firmly tied during the period when Samuel Bentham and Marc Brunel (father of Isambard Kingdom Brunel) were developing the Portsmouth block making machinery at the turn of the century.

It was Maudslay they approached to build the machines, an order being placed with his London firm in 1802.

Some of Maudslay's employees (Richard Roberts, Joseph Whitworth and James Nasmyth) enjoyed exceptionally distinguished careers, becoming as famous in their own right as their mentor. .17. With such eminent engineers coming from a common stable, it would seem unlikely that each would leave without somehow being influenced by the other. In turn they would influence and be influenced by their own workmen and in a way act as baton passers in the on-going technology diffusion relay.

Private and public collaboration and international diffusion

The particular example of technological diffusion which is about to be discussed will illustrate how it was possible for two fundamentally different organisations to cooperate. A collaborative project between the Colt's Patent Fire Arms Manufacturing Company of London in the private sector and the Royal Small Arms Factory at Enfield Lock in the public sector allowed the latter the opportunity to provide a service to an overseas third party, the Egyptian Government.

In 1865, Colonel Esslatoun Bey of the Egyptian Service drew up an agreement with Colt's for the supply of 2,000 pistols and spare parts for the Egyptian Government. Bey, having the responsibility for negotiating the terms of the pistol contract, wrote "They are to be proved here in England in conformity with the existing laws of the Country". Enfield was appointed to carry out an independent inspection of the weapons. Between the 10th and 22nd November 1865 1,025 pistols were received at Enfield. The first inspection certificate clearing the batch was signed by Lt. Colonel Dixon on 22nd November. Referring to the delivered quantity, Dixon stated "Of this number 1000 have been accepted and are marked, as passing the Ordinary Government View". Dixon also signed the second certificate on 30th November which shows that 1,000 pistols passed the "view" out of a delivery of 1,036. Also cleared was a quantity of accessories which included 2,000 nipple wrenches and 100 pairs of bullet moulds. The third certificate concerned spare parts delivered to Enfield for inspection between 13th and 22nd December. By listing these items in full and by analysing the figures, it is possible to make a number of interesting observations which will add to our knowledge and understanding. This not only relates to diffusion through cooperation, but also allows knowledge of the standards of quality and finish which were being achieved at the time.

Received		Accepted	
Main Spring	1001	1000	
Sear Spring	1004	1000	
Cones	12023	12000	
Bolts	400	400	
Hands	400	400	
Screws (counted)	5607	5600	counted
Hammers	200	200	
Triggers	200	200	
Levers & Rammers	200	200	
Keys	200	200	
Cleaning Rods	2052	2000	

> The above number of spare parts have been packed in 2 cases numbered respectively 42 and 43 sealed down and directed to the Minister of War Cairo, Egypt and taken away by the Carrier at the request and to the order of Colt's agent for transmission to Southampton on 5th January 1866. This certificate completes the order. .18.

The first striking aspect which can be deduced from the component list is that there are five classifications out of the eleven which have been slightly over subscribed. From this, it would appear that a prior decision had been taken to supply more components in certain categories than was necessary to ensure the required number successfully passed the view which implies a sharing of knowledge. Also a high level of confidence is shown by the manufacturer in the quality and finish of the majority of components supplied which is demonstrated by the delivery of the exact quantity of items. Almost 55% of the components examined had no defects (we can not be sure from the figures of the reject rate, if any, of the remaining 45%). Achieving this level of quality, would suggest that the Colt Company and the RSAF had reached a clear understanding of each other's requirements prior to the start of the contract. To have done this would have required quite precise communication between the two parties with frank information exchanges, almost certainly resulting in the diffusion of methods, techniques and practices to allow Colt's to quickly meet the viewing criteria set by the RSAF. A further deduction which can be made is that since substantial quantities of spare parts were dispatched, interchangeability had become the accepted norm at least by 1866. Knowledge of the benefits of what would now appear to be an established technology had reached the customer, in this case the Egyptian Government, through diffusion of information.

When examining the correspondence contained in the Public Record Office file concerning Colt's and the Egyptian contract, one can not help but notice that the whole exercise appears to have been carried out in a most efficient and business-like way, from supplier, through contractor to carrier. For a project to run so smoothly would tend to confirm that prior communication had taken place with an exchange of information to establish inspection requirements, shipping arrangements and deadlines.

Dixon took on further work from Colonel Bey to view additional quantities of Colt's pistols. However, in a letter dated 27th February 1866 from Bey, Dixon was asked to inspect "Naval Rifles" from J D Goodman and "Seamans Cutlasses" from Mr Mole, both Birmingham contractors. .19. Again this is an example of how standards of precision were diffused through organisations and different companies, who had either been requested, or perhaps had been forced under the terms of the contract to work together. It would also seem to confirm that, since the War Office (formerly "Ordnance") had become involved in the large scale manufacture of military weapons, a greater degree of cooperation had emerged between the public and private sectors. Notwithstanding these remarkable collaborative arrangements, greater opportunities for cooperation and diffusion lay ahead.

On 12th April 1866 Bey wrote to General George at the War Office stating that he had been "commanded" to purchase, on behalf the Egyptian Government, 12,100 muskets from the Colt's Arms Manufacturing Company of Hartford, Connecticut. He requested that Dixon be authorised to "send three Government Comptrollers of Arms to USA for the purpose of viewing the same", adding that the Egyptian Government would pay the expense. .20.

As the research will show, Enfield was about to play (although it was probably not realised at the time) a most significant role in the field of international technological diffusion and the furtherance of acceptable standards of viewing criteria within the gun industry. On Thursday 21st June 1866 three Enfield viewers, Daniel Floyd, William Foster and James Jackson, arrived at the Hartford factory of Colonel Colt in America. Their task was to inspect a consignment of arms which was destined for the Egyptian Government. On arrival, the three viewers were met by General Franklin the plant Superintendent and Mr Lord the factory manager. Prior to leaving England, the men received the following viewing instructions from Dixon:-

1. The barrel lock and breech pins to be taken out and replaced by the Contractors, for the view in detail. The barrel to be plugged with 580 plug, proved if necessary with 5 drams powder proof and service bullet and examined for straightness and soundness.

2. The lock examined for soundness and the pull off regulated from 7-10lbs.

3. The stock to be tested for soundness.

4. The Bayonet neck tested and blade sprung 1.75 inches.

5. The arms to be assembled by the contractor and handed up for final view.

6. The implements and spare parts and where found necessary and practical marked: but this can not be done where they have been hardened.

7. The arms will receive similar marks to those on the sealed patterns.

8. The senior viewer will certify to the arms etc being packed properly and will seal each case in two places over the screw heads with a seal to be provided by Colonel Dixon for that purpose.

9. The senior viewer will draw up weekly or monthly certificates. Certificates to be in triplicate.

10. The senior viewer will keep a daily register of the number of arms viewed and passed and will transmit a statement every fortnight to Colonel Dixon.

> 11. In order to satisfy Colonel Esslatoun that these arms are interchangeable the senior viewer will take 100 of them and have them stripped, viz the lock complete stripped, the barrel taken out of the stock and the furniture removed - They will then be reassembled, the parts being taken indiscriminately and a report will be made to Colonel Dixon of the result of the examination.
>
> Jackson: to view the barrels, bayonets and implements.
> Foster: to view the locks and weigh the pull off.
> Floyd: to view the stocks and finished arms complete.
>
> The contractors to pack the arms. .21.

Prior to the viewer's embarkation, the Colt Company had supplied three sample rifles to Enfield of the "American Government Pattern, with Bayonets and Appendages". These arms were firstly proved at the RSAF, marked and sealed with the factory seal. One sample was retained by Enfield, one was sent to the Colt Company and the other dispatched to Colonel Bey.

Following the progress of the viewers and briefly sharing their experiences as they inspect the American weapons will allow a unique insight into mid 19th century trans-Atlantic quality standards. From the first letter from Floyd to Dixon dated 2nd July it is learned that the initial inspection of 100 rifles for interchangeability could not be completed for over a week as the viewer's tools, sent on ahead, had been detained by U.S. Customs in New York. Also the American sealed pattern rifle sent beforehand from Enfield had not arrived. This had caused Floyd to make the following highly revealing remark, "The pattern gun is a thing they seem to have no idea of". .22. If it was not usual practice for American armouries to refer to the sealed pattern as a reference standard, then clearly both parties had learned something of each other's manufacturing methods. This provides another example of technology diffusion.

Although the sealed pattern had not arrived, it was decided to view the 100 rifles and check them for interchangeability as directed in Dixon's instruction. Jackson proved the barrels, doing all the loading and firing himself. Four were rejected "for greys inside". The locks were "all stripped and thrown into a heap and assembled again they interchange well. The extra parts interchange into the locks without alteration 100 viewed, 70 marked, 30 returned for soft springs and bad bents". Of the stocks, 80 were marked and 20 rejected, "the greater part for worm holes, then galls". The three viewers diligently proceeded with their work until they had satisfactorily completed the inspection of 12,100 weapons and accessories, the last of which was crated on Friday 14th September, almost three months after their arrival. .23.

By analysing the correspondence it can be seen that the viewers were able to demonstrate to their American counterparts different standards and methods of inspection. This would seem particularly relevant in relation to the sealed pattern, an item not apparently used at the time by the Colt Company. The influence of the Enfield viewers had extended beyond the factory walls, reaching at least one of Colt's suppliers. Referring to problems experienced towards the end of the Egyptian contract, Floyd wrote, "The view of the last 400 was rather slow owing to some stocks the Colt's Co. got made at Windsor Vm. being small and roughly machined. I picked out the best and rejected the rest wholesale, these were the stocks they intended to supply as the extra". .24.

By following the work of the Enfield viewers through an American company, it can be seen that the Egyptian contract had given them considerable power. This had allowed them to impose, through an inspection procedure devised in England, strict standards of quality which had influenced not only internal factory processes but those of external suppliers as well. One can only speculate as to the probable standard of product quality which might have left the Colt factory for Egypt had the RSAF Enfield viewers not been appointed to the task of inspection.

It would be difficult to believe that the British viewers had not in some way been influenced by the experience of being exposed to almost three months of an American factory environment. This particular example would seem to provide further evidence of two-way technological diffusion which, in this instance, occurred more via the spread of ideas, methods and acceptable quality standards rather than by the actual transfer of technology through manufacture and design.

The market as the "engine" of diffusion

It has already been emphasised that the quest to manufacture product by a system of machine tools turning out standard interchangeable parts was not the vision of the small arms industry alone. As consumer demand for various goods increased, ways had to be found to satisfy market needs. This in turn prompted engineers to investigate, more vigorously, technologies such as standardisation as a means of increasing output to meet demand and control costs. The late 18th century endeavours of

Joseph Bramah, assisted by Henry Maudslay, in standardising lock manufacture and the early 19th century success of Samuel Bentham and Marc Brunel in achieving mass production of ship's pulley blocks is evidence of the need to fulfil this criterion.

According to Samuel Smiles, before Maudslay was called in to help Bramah in 1789, "Bramah was still unable to produce his locks to the required degree of accuracy sufficiently fast to satisfy market demand, particularly at a reasonable price". The urgency of achieving these goals had been provoked by a growing awareness and an increased fear of crime by the public. .25. Britain's war with France had fuelled the Royal Navy's requirement for ship's pulley blocks and the shortage had created a market demand. Persuaded by Samuel Bentham, who in 1796 had been appointed Inspector General of Naval Works, the Government undertook the responsibility of block manufacture at the Portsmouth Dockyard by placing orders for a sequence of wood-working machines. The design of the machinery has been mainly attributed to Marc Brunel, the manufacture and construction being completed by Henry Maudslay. .26. Carolyn Cooper has succinctly described the epoch thus:-

> The emergency acted as a focusing device to pinpoint inefficiencies in the old mode of blockmaking by contractor. Once Brunel and Bentham focused on the problem thus posed, the public funds deployed by the navy provided capital for putting into effect their joint solution to the problem. .27.

The shortage of blocks and the measures taken to overcome them has demonstrated that the market helped create the climate for cost effective production, placing the Admiralty in the position of a major consumer. In terms of technological diffusion, it can be seen that the market had provided the "engine" to drive up product demand, provoking the development of the machine tool industry to support it. These conditions acted as the catalyst to reduce overhead costs allowing goods to be produced more cheaply, this being largely achieved through the introduction of increasing amounts of machinery, which in turn created division of labour. The overall effect was a reduction in the reliance upon the talents of highly skilled workmen who had in the past provided the pulley blocks through the contract system. So it can be seen that while machinery de-skilled some a need had been created for unskilled people to join industry as machine operators and minders to service a market led demand. This in a way caused the machine technology to be transferred to a wider and increasing workforce, making many semi-skilled.

As the century progressed, examples of mass production involving machine tools would become increasingly prolific as consumerism began to take hold. Roderick Floud supports this notion when he suggested that:-

> The increasing specialisation and differentiation of the engineering industry was a response to the development of many new products and techniques of manufacture in the second half of the nineteenth century. The development for example of the electrical industries, of cycles, typewriters, sewing machines, automobiles and boot and shoe machinery, of improved steels and alloys, and of methods of power transmission and generation, all called for new manufacturing industries and techniques. .28.

Floud makes a further important point, which gets to the heart of the diffusion debate, when he refers to the necessity of the machine tool industry to be in "... constant readiness to respond to new opportunities ..." He sees the development of machine tool technology in the second half of the century as being "a process of constant accretion to knowledge, not a series of discreet inventions". .29.

Perhaps one of the most illustrative charts to 19th century technological diffusion is Joseph Wickham Roe's "Genealogy of the Robbins & Lawrence Shop" (Fig.29). .30. Here one is able to observe not just the diffusion through movement and the creation of new companies but also, as the century progresses, expansion of the product base from guns and their production machinery, through sewing machines to gear shaping. Although much of the diffusion has occurred through company acquisition and the formation of new partnerships, one can witness and understand the natural relationships which produced a product "spin-off" effect, having market demand as its creator. Therefore, in these particular circumstances, the market has been the dominant force which created the climate allowing diffusion to take place.

Deliberate diffusion

While some technological diffusion occurred naturally through workers moving between different companies and countries, there was a more formalised and deliberate way of transferring knowledge. For example, the 1854 Commission to America was sent specifically to gain information for the British Government on the manufacture of small arms by machinery and, if satisfied with what they saw, to place orders for machine tools. The report of the visit shows a high degree of openness and willingness on behalf of the American National Armouries and private companies to share information with the British Commissioners. There appears to be no obvious fear of industrial espionage by their hosts. While in the United States the Commission took the opportunity to visit a number of manufacturing establishments (not just those concerned with small arms) to study the processes and check the commitment to mechanisation and the amount of machinery employed. Again the Commissioners were afforded the same openness, apparently without hindrance. .31.

As discussed earlier, the Commission placed substantial orders for gun making machinery with Robbins & Lawrence and the Ames Manufacturing Company and engaged James Henry Burton, a highly experienced engineer who had worked in the Government armouries of America, to supervise its installation at Enfield. Here we have seen the calculated and deliberate diffusion of machine tool technology and know-how from America to Britain. One might, therefore speculate that in this particular instance, the overriding factor for allowing such a major transfer of technology was the growing need for the U.S. Government to export revenue generating products. If this was the case it would seem fair to assume that the probable risks had been calculated beforehand. This being so, it would tend to indicate that the necessity for protectionism and the need to maintain long term technological supremacy had been outweighed by a growing exigency within the United States to become an exporting power. Over the years, experience has shown that inventors and developers of leading edge technologies can only stay ahead of market competition for a short time. Therefore it is not unusual for manufacturers of new products, processes and services to make a committed decision to sell their technology at a premium in the short term, before copying or counterfeiting by competitors forces profit margins down.

If a product is perceived to be designed well and functions efficiently, it is not unusual for designers from a competitor to copy certain features. Slight changes might be made to prevent patent infringement but considerable sums of money can be saved by effectively reducing market introduction times and shortening the product's normal design and development phase, and, of course, if the original product is in demand, then the market opportunity has already been created for the counterfeit. As these practices are not uncommon today, one might suspect the need to capitalise on a product before it is copied is not new.

Merrit Roe Smith has pointed out that a deliberate policy of knowledge sharing and cooperation was encouraged between the American national armouries of Springfield and Harpers Ferry. He particularly suggests that an "enduring collaborative effort came after the War of 1812". Describing the mechanisms for this, Roe Smith explains:-

> Initiated by the Ordnance Department, pursued by Roswell Lee, and countenanced by James Stubblefield, both armouries not only shared general administrative information but exchanged men, machinery, and raw materials as well. While everyone profited from the experience, the opening of these channels particularly favoured Harpers Ferry because new technical knowledge tended to flow from Massachusetts to Virginia. .32.

It was not just the American National Armouries who cooperated with each other. There was also considerable activity with manufacturers and suppliers from the private sector, as Roe Smith's research shows:-

> Springfield, situated in a region that abounded with

> foundries, machine shops, and mills of all sorts, provides an instructive case in point. Under Roswell Lee the national armoury adopted a Worcester firm's method of welding gun barrels with triphammers, purchased castings and engine lathes from David Wilkinson of Pawtucket, Rhode Island, lent tools and machine patterns to private business companies, and readily shared information with Eli Whitney, Lemuel Pomeroy, and many other arms contractors. .33.

Of course the deliberate sharing of information with suppliers and contractors on a need to know basis often makes good commercial and engineering sense, ensuring a project's speedy conclusion. Normally this can be achieved through trusting business relationships built up over many years. However there is always the risk of industrial espionage and sometimes there is a need to protect confidentially of technical products and processes by legally binding agreements signed by the participating parties.

The registration of patents is a further method of protection, although there can be certain disadvantages with this procedure. By registering a patent the invention or idea normally goes into the public domain, thereby allowing others to share the innovation. It is then possible for a struggling designer to seize from the patent a new concept and by altering it slightly incorporate it into his own development, thereby solving a particular problem. This can also be done in the knowledge that the original patentee may not wish a long and costly challenge through the courts. The act of registering a patent is in fact another method of carrying forward technological diffusion. While confidentially agreements and registration of patents have their commercial risk, the hazards of information sharing would no doubt have been carefully weighed up by the various parties before decisions were taken either to cooperate in a joint venture or to make public an idea.

Other examples of diffusion have come about through a more unusual route, with a deliberate policy by the perpetrator to defraud and cheat. Such a case was reported in evidence to the 1854 Select Committee on Small Arms, when John Barnett, a London gunmaker, made the following submission in relation to certain Belgium gun manufacturers:-

> ... I will just state my own experience as regards the Liege gun-makers. I have been injured exceedingly by their conduct for the last three or four years, and I am now engaged in a law-suit with several of the Liege manufacturers for counterfeiting my name. My arms go into competition with theirs in various foreign parts, and they have adopted a system of forgery, on taking my name, address, and trade marks, and putting them on their own spurious imitations to a very large extent. .34.

This example illustrates the fact that once a product has been launched into the market place the manufacturer is at the mercy of any unscrupulous individual. Of course counterfeiting, a well known and established product is more likely to be commercially viable. The situation is not dissimilar to the sale of fake Rolex watches today. Nevertheless, the mechanism for these fraudulent enterprises can still be regarded as technological diffusion, as the deceiver and his accomplices still require the skills to gather, understand and interpret the technology to be able to replicate it. Therefore, it can be recognized that, even in a product that perhaps does not strictly conform in every way to the original, technology transfer has taken place.

Diffusion through other formal routes

The Great Exhibition of 1851 in London's Hyde Park gave entrepreneurs and manufacturers the opportunity to display and demonstrate a range of products, processes and technologies on an international scale. Apart from providing a platform for the exchange of views and ideas by industrialists, scientists, engineers and those involved with manufacture, the exhibition enabled a much wider audience to be inspired by a vision of what was possible and achievable. It is therefore conceivable that this in turn would have the effect of raising individual expectations, irrespective of class barriers, and fuelling the "engine" of consumer demand.

Johann Conrad Fischer, a Swiss inventor, entrepreneur and industrialist who exhibited his steel making process at the Great Exhibition, also took the opportunity to record some of the types of visitor in his diary. We in the 20th century can experience some of the atmosphere of the occasion through part of Fischer's entry for 30th June 1851:-

> The example of the Queen in sending her sailors to the Exhibition has been followed by others for the benefit of those who cannot normally get to the Crystal Palace because of the nature of their work, because they live too far from London, or because they have not enough money. Orphans and schoolboys, for example, have been taken to the Exhibition. As I was sitting at breakfast I saw on two occasions parties passing in five coaches. The members of one party were standing in so called "vans" while others were in coaches provided with seats. All coaches were decorated with flags and boughs of trees. Each was drawn by four horses. Over 300 persons-they were workers from two factories-were accommodated in each group of five coaches. For good will many others must be coming to the Exhibition in the same way ... .35.

The excitement of ordinary people going to the Exhibition is conveyed through Fischer's writings. Their imaginations fired by what they had seen and the breadth of ingenuity and technology surrounding the exhibits, would no doubt be discussed and communicated to others. In this way many people would glimpse the future and share in the expectation of what technology might bring. Diffusion of the possible had been taken from the inventor and passed through the product to the consumer. Demand would surely follow.

Further ways of deliberate diffusion can be observed when examining the journals and proceedings of the many learned societies. Information disseminated through papers presented to bodies like the Institute of Mechanical Engineers show more than a one way flow. During the debates which tended to follow the conclusion of a lecture, ideas and opinions freely flowed in both directions between the floor and the rostrum. To ensure the maximum spread of knowledge, it was usual for Societies to arrange lectures for their membership in different parts of the country. In a lecture given to the Birmingham section of the Institute of Mechanical Engineers in 1862, entitled, "On the Application of the Copying Principle in the Manufacture and Rifling of Guns", John Anderson, the chief engineer at Woolwich Arsenal commenced thus:-

> At the Newcastle meeting of this Institution in 1858 the writer gave a paper on some applications of the Copying or Transfer principle in the production of wooden articles. The object of the present paper is to give a continuation of the same subject with reference to productions in metal, more especially in connection with the manufacture of rifled guns or similar structures. .36.

This example not only shows the dissemination of technical information around the country to different groups of engineers but also demonstrates that the presenter has deliberately chosen to ensure that there is "continuation" of his theme in another material. Anderson, who worked for "Ordnance", was a Government employee. Therefore it is significant that he was freely transferring technical information, through his lectures, to the private sector. In fact, the exercise can be seen as going much further as, at the end of the meeting, the Chairman moved a vote of thanks to Anderson and in his following announcement observed:-

> ...that the members would have an opportunity of visiting the works at Woolwich and seeing the whole of the processes described in the paper in the manufacture and rifling of the guns; and also of visiting the Small Arms Factory at Enfield, where the same principles have been carried out by Mr Anderson, and the same accuracy of workmanship attained. .37.

Research has been able to uncover many more instances of technological diffusion within the 19th century which support the findings recorded in this chapter but to include them here would probably add little to the debate. The examples chosen have been included specifically to illustrate some of the more subtle ways in which the transfer of technology occurred. Although many of the examples given are deliberate acts of technological diffusion, others may not always appear obvious to the casual observer.

Tracing technological diffusion from the latter half of the 18th century to the middle of the 19th century shows a gradual change from a position of industrial secrecy to one of considerable knowledge sharing. When discussing the latter part of the 18th century, David Jeremy has pointed out:-

> Secrecy was preserved in several ways. Factories assumed the defensive features of a medieval castle: main shops built around a quadrangle yard, small windows and narrow gateways, as in Benjamin Gott's Bean Ing Mills at Leeds. Workers were sworn to secrecy. Robert Pilkington, who claimed to have

> invented the spiral application of fillet or garter card silver, told Arkwright in 1775 that he and his partner "proposed swearing the hands we employed that they should keep a secret." .38.

From these extreme examples highlighted by Jeremy, it has been shown through earlier illustrations in this chapter that technological diffusion had evolved to almost a completely opposite position by the middle of the 19th century on both sides of the Atlantic. The migration of skilled workers, the passing of skills down through family businesses, lectures to learned societies, articles in respected journals, international and national trade, exhibitions, factory visits and even counterfeiting, all contributed to the transfer of knowledge and the gaining of expertise by others. While it is difficult to explain comprehensively the rapid speed towards technological openness in purely simplistic terms, one is, however, able to appreciate that the maintenance of secrecy would have considerably jeopardised technical progress resulting in loss of market share to the participants, eventually leading to technological stagnation. The problem for leading manufacturers of innovative machinery and products even today is how to stay in business profitably and keep ahead of the market. Once the new product has been launched, manufacturers are in front of their competitors only by the amount of time it takes to introduce the next more advanced piece of merchandise. If manufacturers are capable both technically and financially of sustaining new product launches on a regular basis with a view to increasing or maintaining market superiority and share, then it would seem reasonable to assume that the market is dictating the pace of technological change as well as the rate of diffusion.

NOTES

.1. Jeremy, David J, Transatlantic Industrial Revolution, Basil Blackwell, (Oxford 1981) p.4

.2. Smith, Merrit Roe, Harpers Ferry Armoury and the New Technology, Cornell University Press, (London 1977), pp.88-91. Also see, Felicia J Deyrup, Arms Makers in the Connecticut Valley, Smith College Studies in History, (Northampton, Massachusetts 1948), p.87
Both authors have attributed early forms of standardised gun locks to the 18th century French armourer, Honore Le Blanc. Roe Smith also suggests that Eli Whitney "...probably gained inspiration from Blanc's work".

.3. British Library, London.
Observations on the Manufacture of Fire-Arms for Military Purposes, an anonymous document, Longman & Co. and James Drake, (London 1829) p.34, British Library Catalogue No. 08820 b 25. George Lovell, the superintendent of the RSAF some time after the publication of this document, has hand written extensive comments and made observations on the fly sheets opposite the main text.

.4. Department of the Interior, Fire Arms and Ammunition, Fitch, Charles H, (Washington 1882), p.7

.5. Op.cit., Smith, pp.111-112

.6. Roberts, G H, History of R.S.A.F. Enfield Lock, (C1930), Unpublished manuscript, Ministry of Defence, Pattern Room, Nottingham, p.C10

.7. House of Lords Record Office, London, Report on the Committee of the Machinery United States of America, 10th July, 1855, p.23 (569)

.8. Putnam, Tim & Weinbren, Dan, A Short History of the Royal Small Arms Factory Enfield, Middlesex University, (Enfield 1992), p.39

.9. House of Lords Record Office, London, Report on the Manufacture of Small Arms, 28th, February, 1887, p.50
Also see p.376 section giving full evidence.

.10. Op.cit., Putnam & Weinbren, p.39

.11. Lumley, Roger, "The American System of Manufactures in Birmingham: Production Methods at the Birmingham Small Arms Co.", Business History, No.31, 1989, pp.35-36

.12. Ibid., pp.35-36

.13. Ibid., p.35

.14. Public Record Office, Kew, Supply 5/886

.15. Beaumont, Richard, Purdey's the Guns and the Family, David & Charles, (Newton Abbott 1984), pp.13-15

.16. McNeil, Ian, Joseph Bramah: A Century of Invention, 1749-1851, David & Charles, (Newton Abbott 1968), pp.46-52

.17. Gilbert, K R, The Portsmouth Blockmaking Machinery, HMSO, (London 1965), p.1

.18. Op.cit., Public Record Office, Kew, Supply 5/886 There is extensive correspondence in this file relating to contract work by the RSAF Enfield for the Egyptian Government.

.19. Ibid., Supply 5/886

.20. Ibid., Supply 5/886

.21. Ibid., Supply 5/886

.22. Ibid., Supply 5/886

.23. Ibid., Supply 5/886

.24. Ibid., Supply 5/886

.25. Op.cit., McNeil, pp.44-46

.26. Op.cit., Gilbert, pp.1-3

.27. Cooper, Carolyn C, "The Portsmouth System of Manufacture", Technology & Culture, Vol.25, No.2, April 1984, p.217

.28. Floud, Roderick, The Machine Tool Industry 1850 - 1914, Cambridge University Press, (Cambridge 1976), p.20

.29. Ibid., p.20

.30. Roe, Joseph Wickham, English and American Tool Builders, Humphrey Milford, (London 1916), pp.186-187

.31. Op.cit., Report on the Committee of the Machinery United States of America, pp.64-74

.32. Op.cit. Smith, p.138

.33. Ibid., p.104

.34. House of Lords Record Office, London, Minutes of Evidence Taken Before the Select Committee on Small Arms, Vol. XV111-1854, p.337 (375)

.35. Henderson, W O, J.C. Fischer and his Diary of Industrial England 1814-1851, Frank Cass & Co. Ltd., (London 1966), p.165

.36. Anderson, John, "On the Application of the Copying Principle in the Manufacture and Rifling of Guns", Institute of Mechanical Engineers, Proceedings, 1862, Birmingham, p.125

.37. Ibid., p.145

.38. Op.cit., Jeremy, pp.36-37

CONCLUSION

The subject of this thesis has been the development of the Royal Small arms Factory (Enfield Lock) and its influence upon mass production technology and product design. As the research progressed it was found that the subject under investigation was highly complex, having many influencing strands which it would also be necessary to study. For example, several leading historians have claimed that during the first half of the 19th century the British small arms industry was technologically backward in terms of military weapon manufacture, in comparison to its American counterpart, after first leading the world in the 18th century. This led the thesis to a broader study of the environment within which Enfield developed and grew.

While it can be argued that the British gun trade failed at an early stage to take full advantage of the wealth of inventive engineering skills of men like Bramah, Maudslay, Nasmyth and Whitworth, it has clearly been shown that there was no lack of technological expertise on this side of the Atlantic. Working from the basis that such a paradox existed, it was possible to discover a number of powerful reasons which had caused the British small arms industry to pause technologically and fail to maintain the rate of change which had continued in other areas of manufacture since the industrial revolution. We noted that, apart from seeking individual reasons to explain this phenomenon, many scholars had opted to investigate why America had embraced and developed small arms manufacturing technology, rather than concentrate upon the question of what had held Britain back or, perhaps more correctly, of why manual production methods had remained for so long in England.

Early investigation highlighted a number of separate influences upon the development of the British gun trade, particularly with regard to the private sector. Therefore, subsequent research was directed towards these themes to test their respective strengths. While it might appear that these individual influences are distinct and separate, we have argued that it was a combination of events rather than a single issue which impeded the technological growth of British military small arms manufacturing, restricting the progress of production towards a system of interchangeable manufacture by machine intensive methods. This conclusion might help explain why the debate on Britain's seeming technological backwardness has remained alive for so long, as scholars have tended to examine individual economic and technical issues and have not, for example, linked the politics of the "Ordnance" procurement system to the equation.

We have found no evidence to suggest that, within relevant technical understanding and knowledge, American engineers and entrepreneurs were technically in advance of their British counterparts. However, it is known that the American Government practised within its National Armouries a policy of encouragement to selected entrepreneurs and designers of weapons and machine tools which set them apart from British "Ordnance". Through this policy the United States armouries were able to take advantage, perhaps not consciously, of European innovation which had not been actively embraced by the Board of Ordnance and applied to methods of small arms production in Britain. It has been shown that many of the ideas for self acting machine tools purchased by the British Government from America in the developed state, for use at Enfield were either "borrowed" or transferred to the United States at an earlier stage through a variety of routes and sources. Some of the ideas were carried to America by emigrating artisans, others were derived from freely available technical literature and, of course, there was the opportunity to copy from exported products. .1.

Irrespective of where the constituent ideas originated, American engineers and entrepreneurs, greatly encouraged by the United States Government, had exploited a range of machine tool design concepts and developed them into a system for supporting the manufacture of weapons with interchangeable parts. From this, the production of other goods followed, leading to the explosion in consumerism which has touched the lives of everyone in the modern world. The establishment of the "American system" occurred mainly in the period between the Napoleonic and Crimean Wars when the British Board of Ordnance were wrestling with a host of difficult problems, a major one being whether the public or the private sector should take control of the manufacture of military small arms.

The Royal Small Arms Factory (as it was to become known) at Enfield Lock, although not having a major manufacturing role until 1857, had, since its inception in 1816, acted mainly as a research and development establishment and weapon repair shop.

During this period the private gun trade held the lion's share of military small arms manufacture, firstly through a system of favoured contractors and then, in the late 1840s, by open competition. However, the private sector was not able to move from a hand manufacturing culture to one employing machine intensive methods, as it had been effectively denied the incentive to invest in capital equipment. The problem arose out of the Board of Ordnance operating a policy of issuing only short term contracts. Further difficulties were placed in the way of the private gun trade through a strictly administered "Ordnance" inspection system which demanded high levels of tolerance on parts and complete weapons. Subsequent examination of small arms artifacts with gauges has shown that "Ordnance" were on occasion requiring unreasonable levels of precision without considering the application of the part under scrutiny. Deliberately withholding the issue of patterns and gauges, against which these tight measurements had to be made, caused not only weapon supply problems for "Ordnance" but also affected the stability of the private sector, as skilled artisans left the industry to seek employment elsewhere. Many of these men were permanently lost to the gun trade.

George Lovell, during his thirty eight years as Storekeeper at Enfield and later Inspector of Small Arms, had carried on a passionate crusade to equip the British soldier with the best possible weapons. In his drive for perfection he had imposed tighter standards of inspection on both weapons and parts. This action not only delayed his personal objective but seriously irritated the private sector, making him their enemy and target of derision. Lovell in the early 1840s had tried to find ways of improving the manufacturing efficiency and quality of the private sector's product by proposing a fairer pricing structure and a longer contract period of up to three years. However, he was not supported in this initiative by the Board of Ordnance. Nevertheless, it has been shown that, in spite of the Board's refusal to back him he persevered with his proposal, not admitting to its implementation until some years later. No doubt Lovell's determined action did not go down well and it is clear that this had not endeared him to his superiors.

On another occasion Lovell was able to get his way with his superiors and the incident demonstrates that he was a skillful and astute negotiator. While under pressure from the private gun trade's lobby of Parliament not to expand the "Ordnance" manufacturing facility at Enfield, he was able to construct a gun stock desiccating chamber on the site without serious repercussions. Once Lovell had satisfied himself that the curing of gun stocks could be satisfactorily accomplished within weeks rather than years, he was eager to install the system. Even though the Board of Ordnance were not responding quickly to his recommendations to build the plant, he was able to achieve his objective. He got his way by considerable stealth through a series of veiled threats and suggestions that he would have to get a substantial quantity of gun stocks cured privately, thereby demonstrating that it would be more costly to the Board not to install the desiccating chamber. It has also been revealed through an examination of Lovell's private and public opinions that he was harbouring a hidden agenda to bring military gun making under "Ordnance" control. In the late 1820s Lovell had shown through his private writing that he was an avid believer in Government control of the means of all military manufacture, yet publicly when giving evidence before a Select Committee in the late 1840s he had advocated Enfield should remain a small manufacturing establishment. However, we have been able to discover later evidence that Lovell was being economical with the issuing of patterns and gauges to the contractors. By this action it would appear that he was trying to obstruct the contractors complying with their contractual obligations, thereby provoking a situation which would force "Ordnance" to take control of small arms manufacture. While Lovell's methods might be questioned, there is little doubt that he wished to provide the British soldier with the best possible arms, being frustrated in his attempts to achieve this by an intransigent Board of Ordnance. A hidden agenda might have seemed the only likely option for Lovell to have achieved his ultimate objective of equipping the British soldier with the best possible weapon.

Tim Putnam has suggested that "Lovell would have found a great deal in common with John Hall, who was supervising the manufacture of a breech-loading rifle of his own design at the Government Armory at Harpers Ferry". .2. While it would appear appropriate to compare Lovell with Hall for his inventive skills, drive and determination, there the similarity would seem to end. In fact it is not possible to make a direct comparison between Lovell and any of his American contemporaries as he possessed a range of skills which were quite unique for a man in charge of a government armoury. For example, if one looks at Roswell Lee, the Superintendent of the Springfield National Armoury (the nearest equivalent of Lovell in the United States) it can be seen that both men held similar aims and objectives in the standardisation of small arms and both had a good grasp of production methods. .3. Lee had experimented with simple inspection gauges as early as 1817, while in the early 1830s Lovell was exposing with the use of a new micrometer variations in gauges used at Enfield for checking the calibre of musket barrels. .4. Both men held supervisory positions but Lee, while working for the government, did not pursue, as Lovell did, a personal quest to improve the specification and design of small arms. .5. In the 1820s, Lovell had experimented with percussion caps and showed their superiority over flint ignition. Later, while still Storekeeper at Enfield, he was responsible for the design of several new arms. These aspects of Lovell's expertise in particular set him apart from his ordnance counterparts.

In summary, Lovell can be seen, throughout his career as Storekeeper and later as Inspector of Small Arms, as a man of many parts whose real intentions, that of providing the British soldier with the best possible weapons, were not fully understood by his superiors. Although he promoted strict standards of inspection, which under the "Ordnance" contract system were almost impossible to achieve, this was his way of driving the gun trade towards standardisation within a system of government bureaucracy which had curtailed his ability to negotiate reasonable terms and conditions with the private contractors.

Unfortunately, Lovell paid the price of becoming extremely unpopular with the private sector contractors, souring the gun trade's relationship with "Ordnance".

In contrast to the "Ordnance" arms procurement policy and the strict inspection standards imposed by Lovell, we have learned by examining the evidence of a representative sample of witnesses who came before the 1854 Select Committee on Small Arms how it was possible for the East India Company to obtain large quantities of weapons at reasonable prices from the private sector. This was achieved by the Company adopting a more liberal and practical approach to doing business with the contractors than that of her "Ordnance" counterpart. Interestingly, the East India Company was doing business with the same private sector contractors as "Ordnance" during the period in which these firms were accused by Government of supplying inferior products and failing to meet delivery schedules. The example helps explain the importance of having a good customer supplier relationship where problems can be discussed and mutually resolved. This approach to arms procurement, although not exactly the same as the internal contractor arrangement operated by the American Government, reinforces the concept of cooperation with the suppliers of services and goods, rather than conflict, as the best way of working.

Felicia Deyrup and Merrit Roe Smith have given several examples of how the internal contractor system operated within the American National Armouries to the long term advantage of weapon standardisation and machine tool development. Deyrup has suggested that by 1840 most of the weapon and machine tool development had moved into the control of the private company and away from government. However, it is clear from the Report of the Committee of Machinery to the United States of America that cooperation with the private sector was still present as late as 1854. Here, the action of the Springfield Armoury Superintendent to release his most senior engineer to assist the Ames Manufacturing Company in designing machine tools for the Enfield contract illustrates how strong these links still were. This aspect of cooperation between the public and private sectors has been highlighted by historians as an important feature in the success of American industry in its drive towards standardisation and machine tool development. However, the deliberate lack of cooperation by "Ordnance" with the British gun trade has hitherto not received the attention it deserves in helping to explain the longer reliance on labour intensive methods of production on this side of the Atlantic. Cooperation, or rather lack of it, was just another ingredient in the complex cocktail of events which helped create a pause in the technological progress of the British small arms industry.

The war in the Crimea acted as the perfect excuse for "Ordnance" to take control of military small arms production but new evidence has been provided from the period to illustrate the incompetent nature of the Master General and the Board of Ordnance in matters pertaining to weapon manufacture and procurement. It has been found that successive Masters Generals had been promoted to the position after long and distinguished military and political careers, many being appointed late in life. The backgrounds of these men, being steeped in military tactics and political diplomacy, rendered them totally unsuitable for being in charge of sophisticated weapon manufacturing and procurement programmes. This has been substantiated through the continuing correspondence between Viscount Hardinge and Captain Dixon, which showed that the former had proposed the manufacture of a range of different weapons at the time when the Crimean War was in progress. Clearly this has illustrated that Hardinge was ignorant of the quite detailed preparation and the time-scales required for setting up a new production line, with the necessity to plan the supply, storage and issue of new materials. It also shows that he was unaware of the time it took to design and manufacture gauges, jigs and fixtures when a new weapon pattern was being laid down. Much of this work could only be undertaken by highly skilled tool-room engineers and could take many months to complete.

Furthermore, at the time when Hardinge was contemplating the manufacture of these new weapons, "Ordnance" were still heavily reliant upon contractors for the bulk of their arms supply. This would have meant a change or addition to the current weapon supply programme which would have had to be negotiated, causing further delays by taking time to organise. The other option might have been for "Ordnance" to take the work in-house. In time of war both scenarios were clearly unacceptable propositions, as weapons would be urgently required by the front line troops. Furthermore, experience has shown that most new products go through an initial teething phase until the factory manufacturing processes and personnel become used to the new methods of working. This would have caused further supply delays for the Army.

Throughout the 19th century the military weapon development programme relied upon a Government operated system of open competition which called upon gunsmiths and inventors to submit their designs for evaluation. The system had little or no regard for the method of manufacture, the main criteria being how the weapon performed under battlefield conditions rather than how easy it was to produce and assemble. By pursuing such a strategy, the War Office had failed to appreciate the benefits of cost which could be achieved from a fully integrated weapon design and manufacturing programme. The rationale for this somewhat short-sighted approach, which persisted throughout the second half of the 19th century, is not to be found in reasoned argument in any of the official documents so far discovered. This might therefore indicate that the military administration held a more influential position with Government than the engineering sector.

When the War Office took over responsibility for arms procurement from the Board of Ordnance in the mid 1850s, there was still little attention paid, within the public sector, to ease of military weapon manufacture. This situation continued in Britain throughout the remainder of the century. There were of course "Ordnance" engineers like John Anderson who understood that weapons could be made more cost effectively by introducing designs with simple curves and angles, allowing faster cycle times on the machine tools of the day. However, there is no documentary evidence to suggest that there was enthusiasm within Government departments for taking these ideas forward. Military weapons were selected on the basis of results obtained through competition which relied mainly on extensive performance trials. It has been demonstrated quite clearly that this policy resulted in the soldier ending up with a small arm of compromise specification. As the results of research have shown, there was always a rejected weapon which performed in at least one particular aspect better than the one which was finally selected. These problems were partially overcome in the 1870s by the introduction of the Martini Henry rifle, combining the best breech mechanism with the most accurate barrel. Nevertheless, there was still no consideration given to ease of manufacture and assembly as part of design criteria. Weapons effectively evolved out of performance improvements over their predecessors.

By taking the opportunity to examine, under an optical microscope, a small representative sample of the Enfield pattern 1853 gun lock tumblers manufactured in three different periods (one before and two after the new machine tools were installed at Enfield) then enlisting the help of time-served engineers from the small arms industry, a greater understanding of a number of controversial issues has been brought about. For example, through a study of the machine and hand tool markings under magnification, it has been possible to establish that the tumblers had been adjusted to niceties of operation by hand filing. From this exercise two further pieces of information have been revealed. Firstly, it was suggested by the engineers that the amount of hand filing was slight, suggesting it was done only for adjustment of the part for ease of fit. Therefore, the amount of metal which would have been removed would not have equated to the figure of "...more than half the man hours required..." for the manufacture of the American pattern 1864 tumbler as Robert Gordon suggests. .6. Secondly, the high standard of finish, coupled with only a small amount of filing on the two later tumblers, might suggest that the newly installed American machine tools at Enfield were more advanced than their Springfield counterparts. If this was the case it would be unfair to make a direct comparison of the Enfield tumblers with Gordon's findings. However, as it is unlikely that artefactual evidence will surface relating to the machine tools which produced the American and British tumblers under discussion, one can only speculate on the possible improvements in accuracy achieved on the later Enfield machine tools.

The use of hand filing to adjust the part to a finer level of accuracy or finish after it has come off the machine has raised the question as to what exactly we mean by interchangeability. Some commentators have implied that interchangeability means that the part requires no other form of adjustment once it has been machine produced. However, while this definition might apply to computer numerically controlled (CNC) machined parts produced with the latest 20th century technology, it can not be applied to mid 19th century machine manufacture. Gordon and others have produced evidence to show that hand finishing was still in use on both sides of the Atlantic during the second half of the century.

Provided the part can fit the gauge accurately and the gauges in use are always referenced to a master set of instruments, then it must be accepted that the part is interchangeable, irrespective of it having been adjusted or finished by hand. Some of the recent discussions on interchangeability have arisen out of the Report of the Committee of Machinery to the United States of America visit to Springfield in 1854. It has been established that much contemporary interpretation of what the Committee had seen and reported, during a specially arranged demonstration of weapon parts interchangeability at the National Armoury, has been based on a false premise. Had commentators challenged the statement that a lock mechanism could be assembled with the use of a "turnscrew only" by physically checking the artefactual evidence, then our perceptions of the level of interchangeability achieved by the mid 19th century may have been different. It has been shown that the Committee had witnessed a complete lock mechanism being swapped as a sub-assembly and it is therefore difficult to judge how close to gauge the individual parts of the lock were.

The new American machinery at Enfield in the mid 1850s was introduced primarily to increase manufacturing output and to provide higher levels of standardisation. There is no doubt that these objectives were achieved, the system quickly proving itself more efficient and faster than the old methods accomplished by manual labour. However, there is no evidence to suggest that the War Office had used this unique opportunity to give thought to the concept of implementing a weapon design strategy which would require arms to be manufactured more easily, with a view to reducing material usage, improving assembly times and cutting production costs. This was because Enfield had been locked into a system of manufacturing an existing weapon design, the pattern 1853 rifle. Nevertheless, we know from Anderson's evidence to the 1854 Select Committee, that the existing pattern could have been produced more cost effectively by introducing some simple design changes. So why had engineering advice apparently been ignored?

Firstly, the tools and machinery had been ordered from America to manufacture the pattern as it stood in 1854 and it would have taken a brave man to interfere with the arrangements at such a late stage. Secondly, Enfield had the problem of dealing with large stocks of the pattern 1853 after the Crimean War. These weapons then became the basis of the next generation of arms when they were converted to the breech loader on the Snider principle. Given the large stocks of small arms and the knowledge that the pattern 1853 could be converted to a breech loader relatively easily, at the cost of under one pound, it would have been no doubt uneconomical to scrap the existing weapon and start with a new, simpler design. However, there is no evidence to suggest that a half-way measure was being considered along the lines of Anderson's suggestions when the new factory came fully on stream in 1857. This would not have meant scrapping the pattern 1853, just altering and simplifying some of the component shapes. Of course some (not all) new jigs and gauges would have had to be made if Anderson's ideas had been adopted but that would not have been a major cost penalty.

By making a detailed examination of more that thirty pattern 1853 hammers from weapons dated between 1852 and 1885, manufactured in both the public and private sectors, it can be established that changes to some of the curved profiles of the Enfield mechanisms did not take place until 1860 (the private sector was much later). The most significant of these was a straightening of the rear underside of the hammer head. This was three years after the Enfield factory started volume production with the new machinery, confirming earlier evidence that there was a reluctance on behalf of the War Office to take the opportunity to make minor design changes to reduce unit manufacturing costs. From the examination of the artefacts it can be established that further changes to the hammer and lock plate followed. These removed the simple but decorative engraving, and allowed a curve on the outside shoulder of the hammer to be straight milled. .7. What is interesting about these changes is that to date no written instructions or references have been found ordering them to be implemented. Of course it is conceivable that production engineers took the opportunity to introduce these changes gradually on the line, with or without official blessing from the military, there being no detrimental outcome regarding the weapon's performance. One might speculate that, because James Henry Burton had been brought from America on a five year contract to oversee the installation of the new machinery, he could have encouraged the Enfield management to consider simplifying the shape of the hammer. After all, he would have been well aware of the similarities between the pattern 1853 lock mechanism and that of the United States Army M.1842 (Figs.30 and 31). The hammer on this weapon was strictly functional, having limited curves and no decorative engraving.

Once the new machinery had been installed and was fully operational, Enfield was placed in a very powerful position, able to dictate terms which would immediately make it even more difficult for the private sector to obtain military contracts. Although it had been recommended by the 1854 Select Committee on Small Arms that the private gun trade should remain a supplier of military weapons, Enfield was again able to play the quality card. Now, and because of the new machinery, they were able to insist that, in future, all weapon parts would have to conform to the system of interchangeability. This had the effect of forcing fourteen of the larger Birmingham contractors to combine and form the Birmingham Small Arms Company (BSA) at Small Heath in 1861, giving them the collective financial power to purchase the necessary machinery which enabled them to tender for future military business. Being forced to invest in machinery to mass produce military weapons was probably an unappreciated blessing at the time but it helped prepare BSA for the future coming boom in consumer products like bicycles. Being a private company, not bound by the controls placed upon a public sector establishment like Enfield by a Government bureaucracy, would have helped BSA to be more flexible in its manufacturing approach and product diversity in times of peace, when the need for arms declined.

The thesis, in addressing the central questions surrounding the seeming slowness of the British small arms industry to relinquish the traditional methods of manual production and adopt a machine orientated culture, together with the influence of the Royal

Small Arms Factory upon mass production technology and product design, has clearly identified that many factors were at play. These were:-

strictness of "Ordnance" inspections;
withholding of patterns and gauges;
short term contracts;
ignorance of the Master General and the Board of Ordnance in manufacturing matters;
an "Ordnance" arms length policy with the private sector; and
forty years of peace.

In an unplanned and surprising way it was the existence of these factors coupled with the timing of the war in the Crimea which acted as the catalyst, provoking the start of a manufacturing technology which was to have far reaching consequences for British industry. Had such factors existed in the United States as they had in Britain over the same period, then one might speculate that our lifestyles today, and perhaps those of the American and other people, may have turned out quite differently. The engineering and manufacturing technologies left the Old World for the New World at the end of the 18th century, then in the middle of the 19th century they returned in a developed state, to be spread further afield into the 20th century with the assistance of the Royal Small Arms Factory, Enfield Lock.

NOTES

.1. Jeremy, David J, "Damming the Flood: British Government Efforts to Check the Outflow of Technicians and Machinery, 1780-1843", Business History Review, Vol.51, No.1, Spring 1977.
To stop the outward flow of technology, the British Government in the late 18th century tried to curb international trade by making the export of certain categories of machinery illegal. It was also illegal for skilled artisans or manufacturers to leave Britain or Ireland for the purpose of carrying on their trade. Nevertheless many found ways of circumventing this, spreading their knowledge and skills.

.2. Putnam, Tim & Weinbren, Dan, A Short History of the Royal Small Arms Factory Enfield, Centre for Applied Historical Studies, (Enfield 1992), p.13

.3. Smith, Merrit Roe, Harpers Ferry Armoury and the New Technology, Cornell University Press, (London, 1977), p.109

.4. Op.cit., Putnam & Weinbren, p15

.5. Op.cit., Smith, p.109-125
From his appointment in 1815, in his drive towards standardised weapons, Lee had actively sought to introduced many new and experimental machine tools to Springfield. These ranged from barrel turning and gun stocking lathes to a rolling mill for barrel iron. There is little doubt that Lee was bolstered in his quest for weapon standardisation by the fact that the American National Armouries actively encouraged the co-operation of private tool makers and inventors. This gave Springfield a considerable advantage over Enfield, which, apart from being small by comparison, had to accept the Board of Ordnance's arms-length policy when dealing with contractors.

.6. Gordon, Robert B, "Who Turned The Mechanical Ideal into Mechanical Reality?", Technology & Culture, Vol.29, No.4, October 1988, pp.752-753

.7. Ministry of Defence Pattern Room, Nottingham, 7/5/96.
By examining a cross-section of pattern 1853 hammers made at Enfield and in the private sector it was discovered that the changes to those manufactured by the contractors came later than the Enfield introductions. However the pattern of evidence is varied, some hammers having only one curve modified, some having at least two and some having combinations with or without decorative engraving. One possible reason for this might be that individual companies had stock-piles of hammers from former contracts. There is also evidence that these varied changes did not always

comply with the sealed pattern. This might suggest that the War Office were adopting a more realistic and practical approach to arms production. The first example of change (straightening of underside of head only) was observed on a Tower sample of 1862. However a Hollis & Sheath Tower version hammer of 1875 had the engraving and all the curves in place, although there was no evidence of engraving on the lock plate. There were also other anomalies that were noticed on some Enfield manufactured weapons. For example, an Enfield converted (Snider) pattern 1853 carbine for the Bengal Light Cavalry dated 1867 retained all curves to the hammer but no engraving of this mechanism or on the lock plate.

Note. A Tower manufactured item was one which came from the private sector rather than the Government factory at Enfield.

General note

Although the writer has gone to great lengths to trace 19th century correspondence between the Board of Ordnance and the private gun trade, the amount of surviving documentary evidence discovered which is relevant to the debate has been small. In an effort to redress this lack of primary source material concerning the public and private sectors, it has been necessary to study carefully the excellent Select Committee reports, some of which carry engrossed copies of correspondence between the Board of Ordnance and the private gun contractors. To ensure the accuracy of this Government published correspondence, which on occasion appears as an appendix to the Select Committee reports, a comparison has been made with the original surviving letters in the Public Record Office, Kew. On all occasions it has been found that there is complete consistency between the correspondence in the Public Record Office files and that which appears in the Government reports. Therefore the writer is confident that by a considered and sensitive treatment of the Government reports, while supporting the research with an examination of relevant artefacts, has allowed an effective study of the thesis objectives to have taken place.

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Fig.1. Musket "Brown Bess", 0.753 inch, c.1797-1815.

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Fig.2. Rifle Baker, Flint Lock, 0.625 inch - c.1823.

Fig.3. Rifle Brunswick, 0.704 inch - c.1840.

Fig.4. Percussion Musket 1842, 0.753 inch - c.1843.

Fig.5. Rifle Musket, Minie Pattern 1851, 0.702 inch - c.1852.

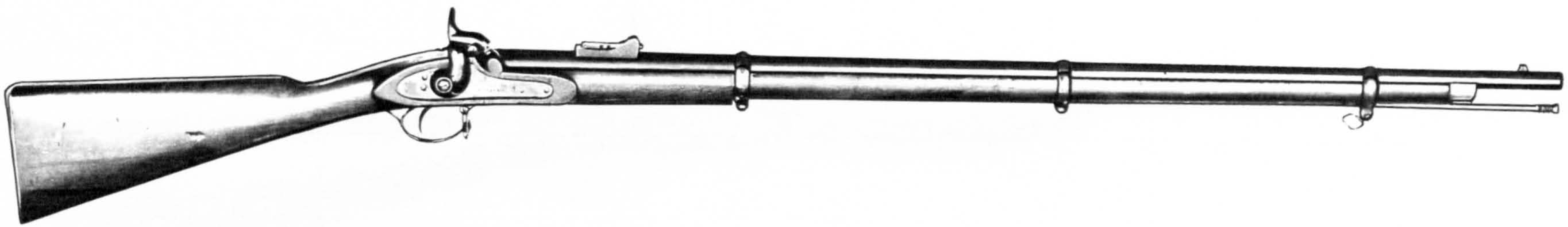


Fig.6. Enfield Rifle Pattern 1853, 0.577 inch - c.1856.

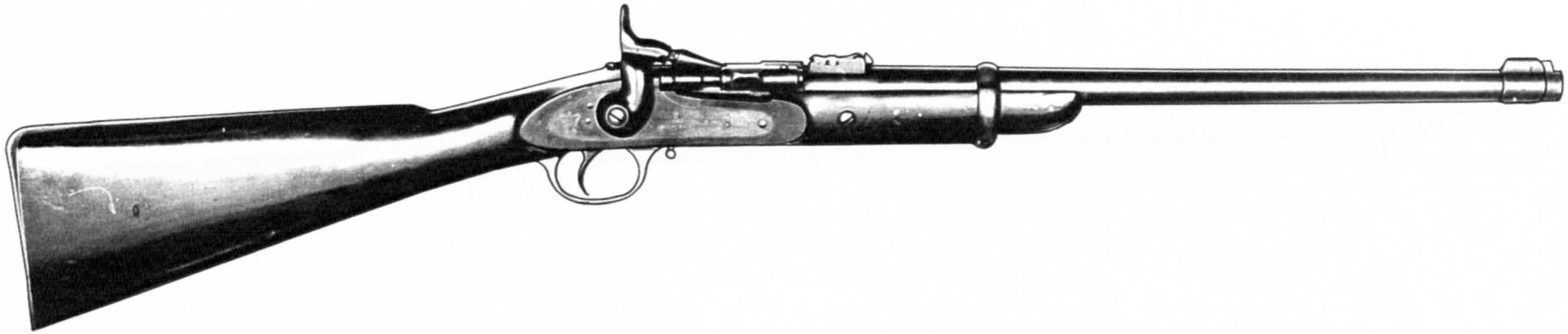


Fig.7. Carbine Cavalry Snider MK111, 0.577 inch - c.1876.

Fig.8. Rifle Martini Henry MK1V, 0.45 inch - c.1887.

Fig.9. Rifle Lee Metford MK11 - c.1892.

Fig.10. Rifle Magazine Lee Enfield MK1,
c.1895.

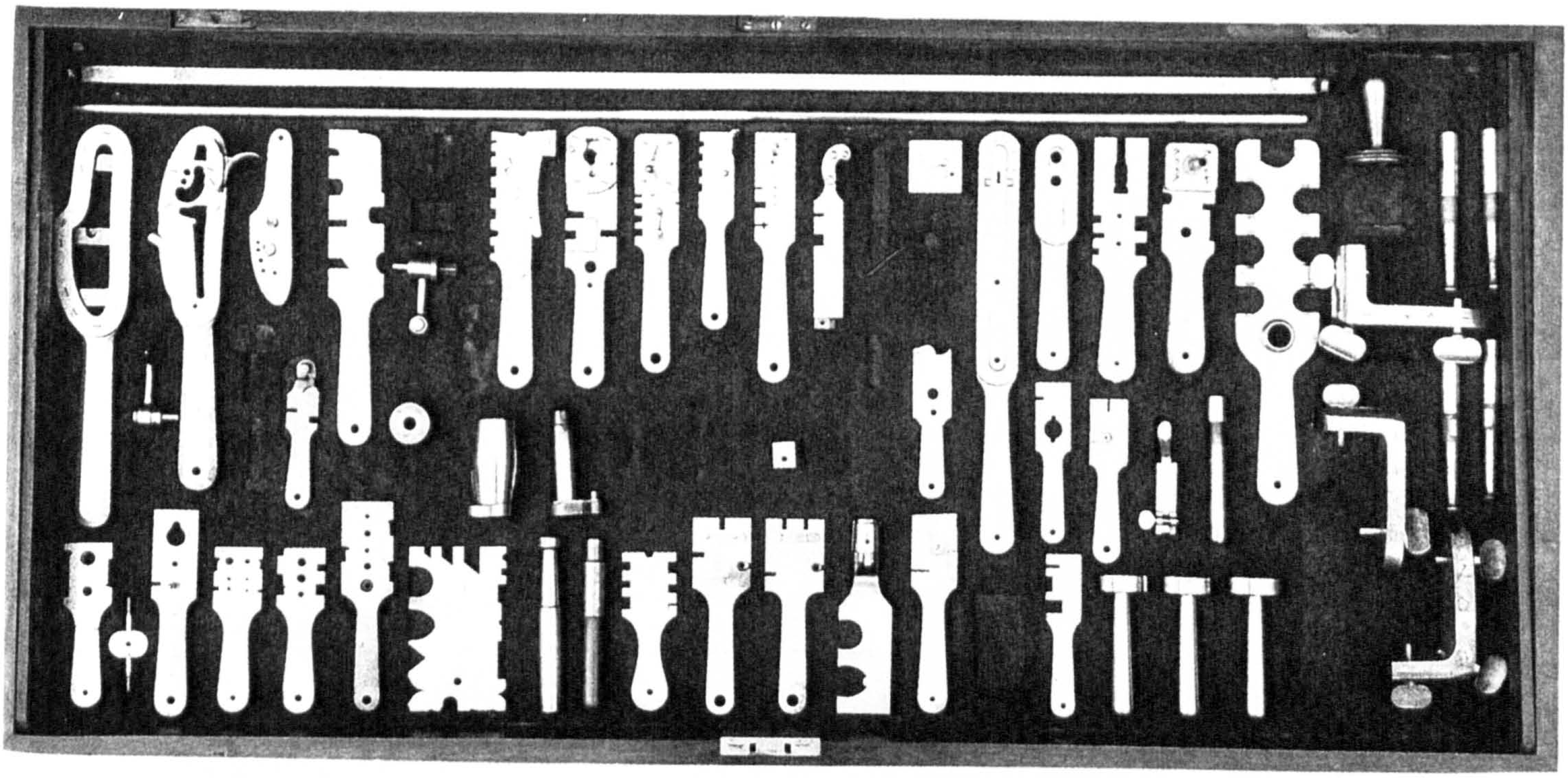


Fig.11. Gauges for the Enfield Rifle Pattern 1853.

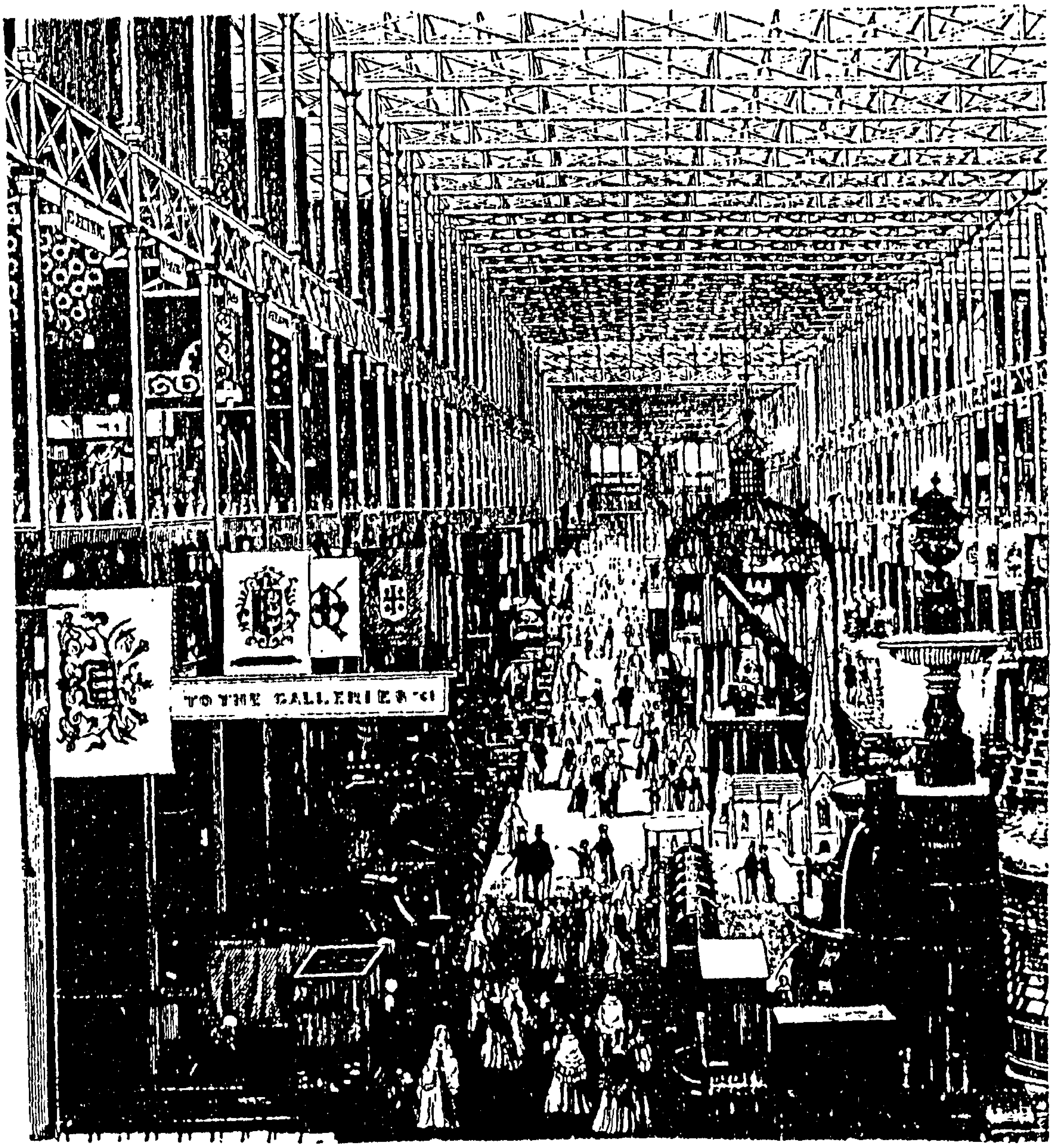


Fig.12. Main Avenue of Crystal Palace Great Exhibition, 1851.
Note uniformity of roof and gallery support structure.
(From an etching by George Cruikshank)

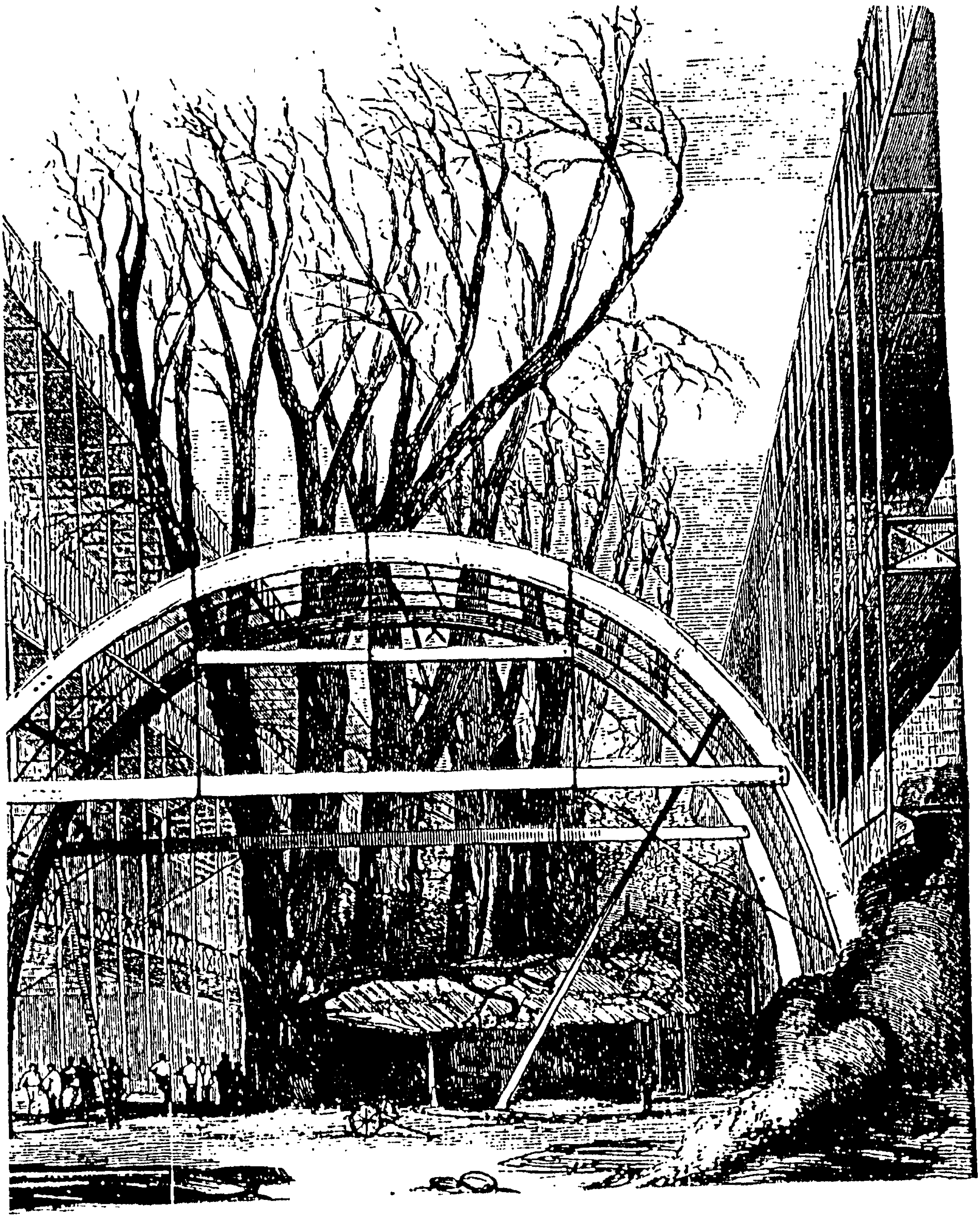
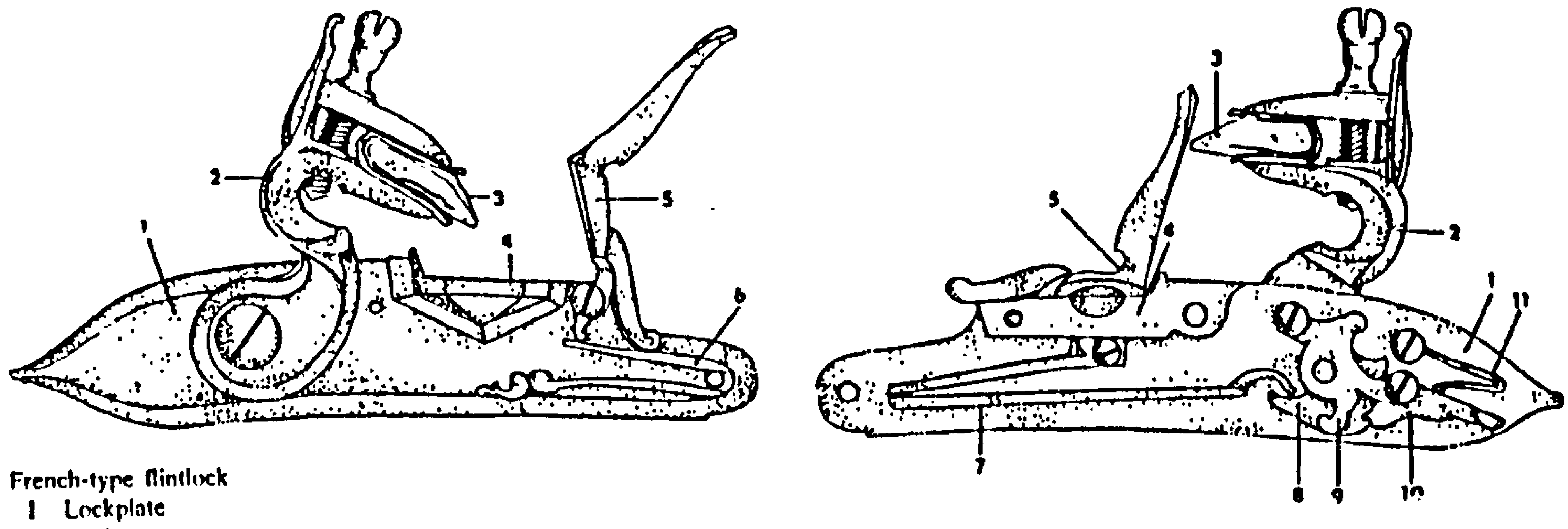


Fig.13. Engraving from "The Expositor", December 1850, showing standardized roof sections which have been prefabricated waiting to be lifted into position.



French-type flintlock
1 Lockplate
2 Cock
3 Flint
4 Pan
5 Battery-frizzen (steel and pan-cover)
6 Spring for steel and pan-cover
7 Mainspring
8 Tumbler
9 Tumbler-bridle
10 Sear-lever
11 Sear-spring

Fig.14. Typical 17th century French style flint-lock (The Encyclopedia of European Historical Weapons, 1993, Line Drawing - Petr Moudry')

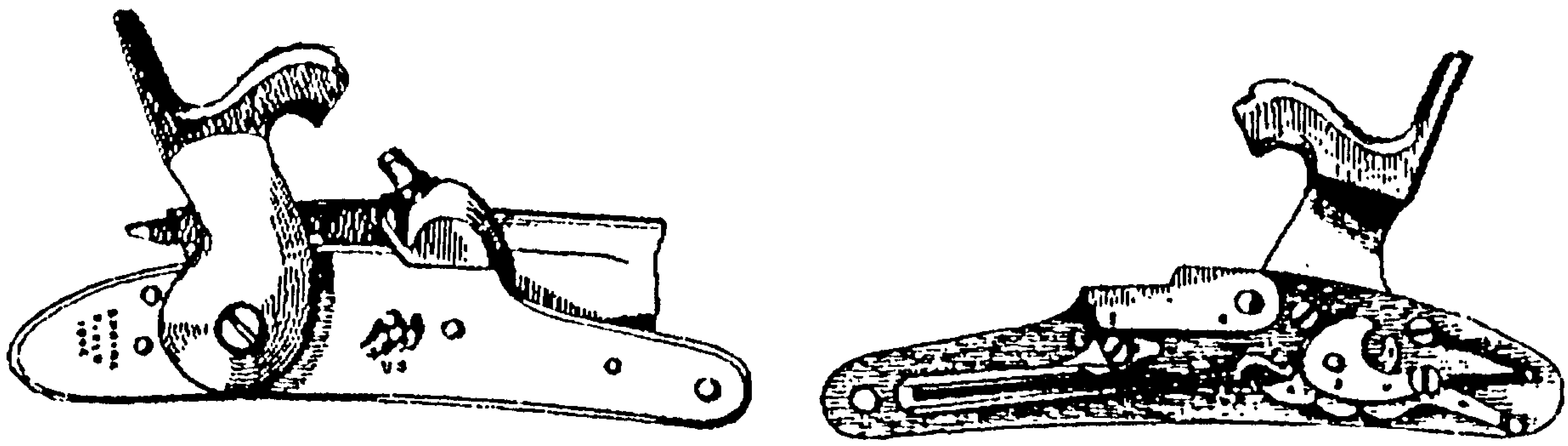


Fig.15. U.S Musket Model 1842 percussion lock (U.S Military Firearms 1776-1956, Major James E Hicks) (Illustrated by Andre Jandot)

THE LOCK

The limbs to be named in the order in which they are removed, viz. :—

1. Main-spring.
2. Sear-spring.
3. Sear.
4. Bridle.
5. Hammer.
6. Tumbler.
7. Swivel.
8. Lock-plate.
9. Tumbler Pin.
10. Sear-spring Pin.
11. Sear Pin.
12. Bridle Pin.

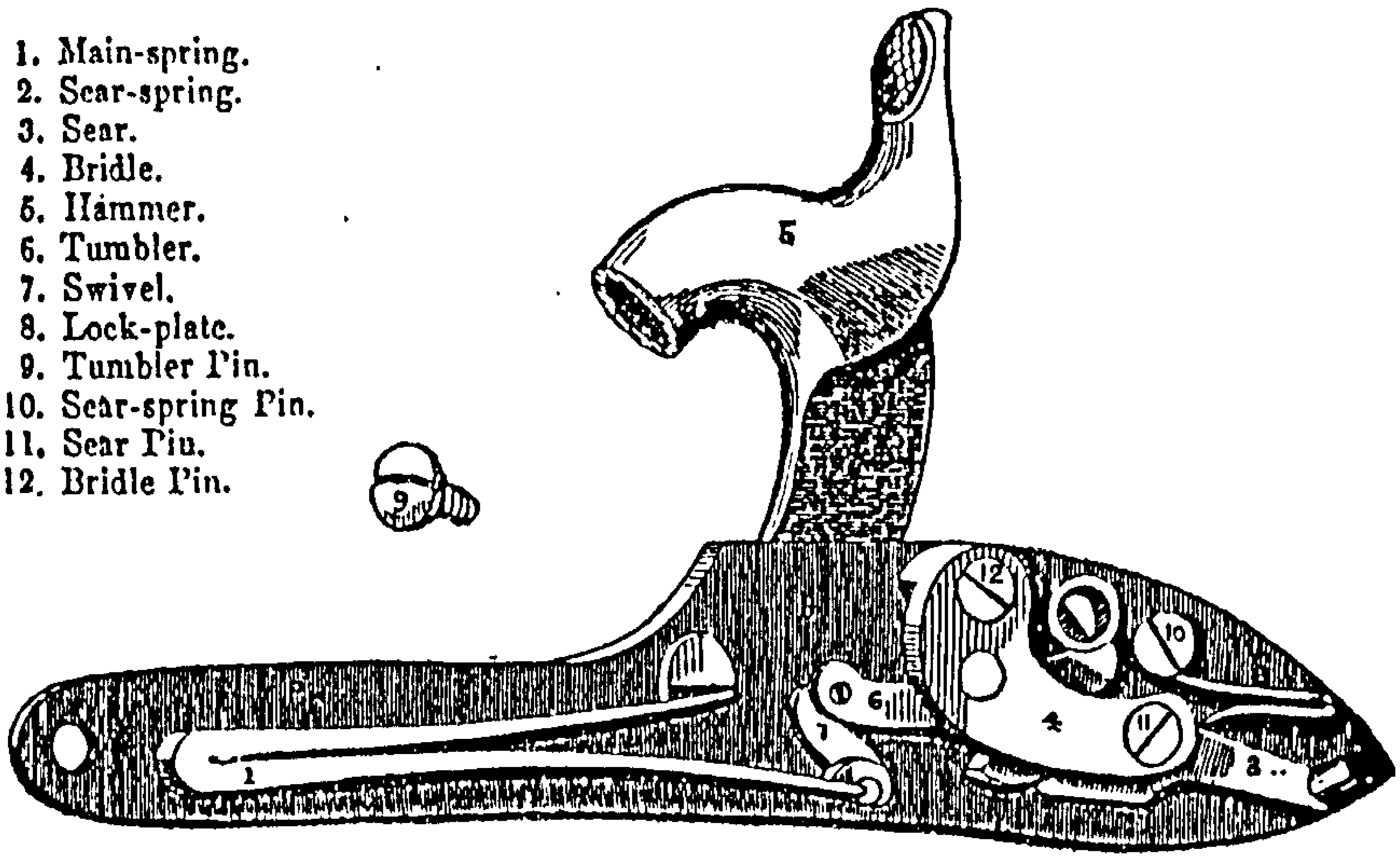


Fig.16. Enfield Pattern 1853 percussion lock (Musketry Instruction of the Army, 1864)

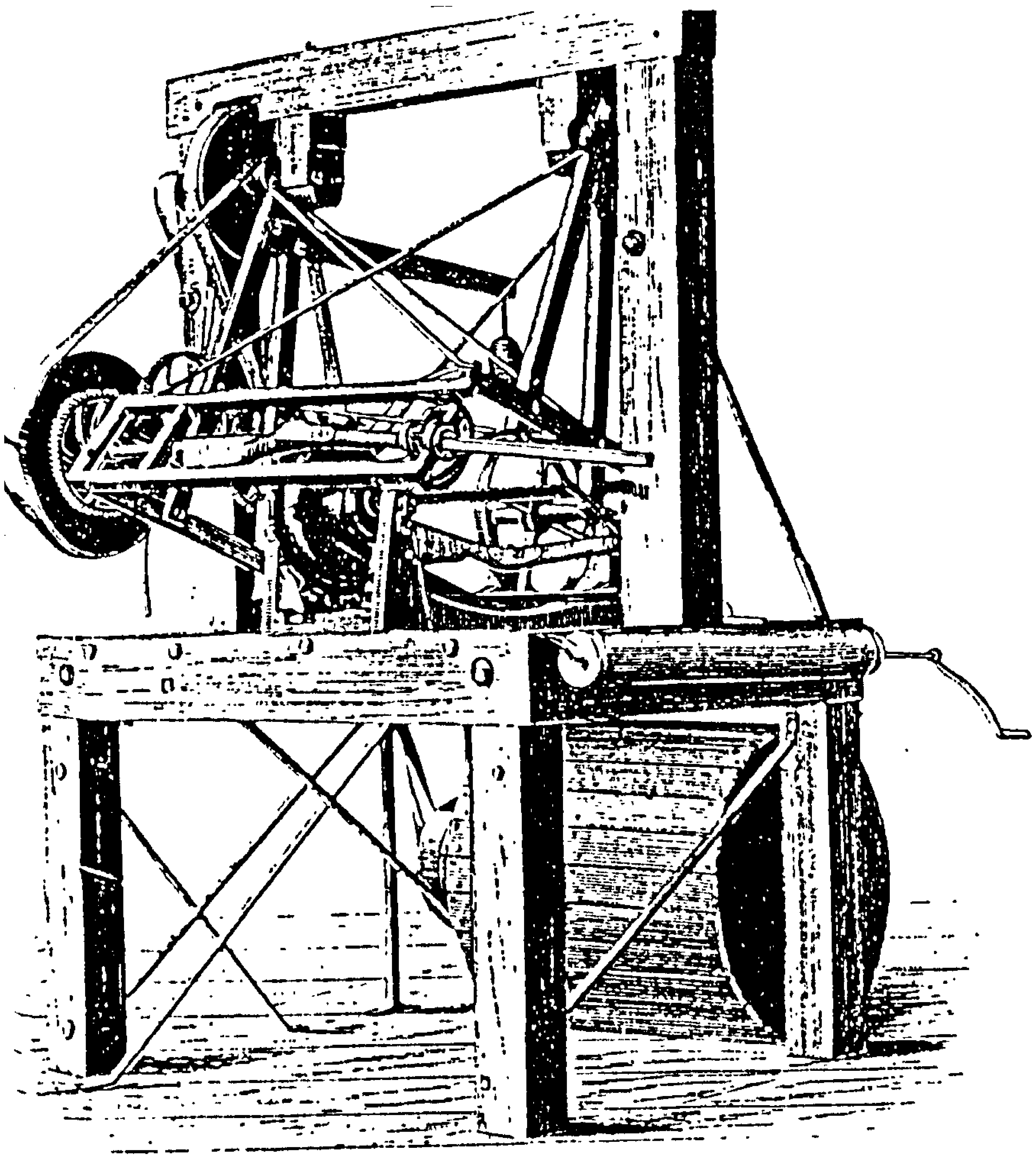


Fig.17. Early Blanchard Lathe c.1822
(Fitch Census Report 1882)

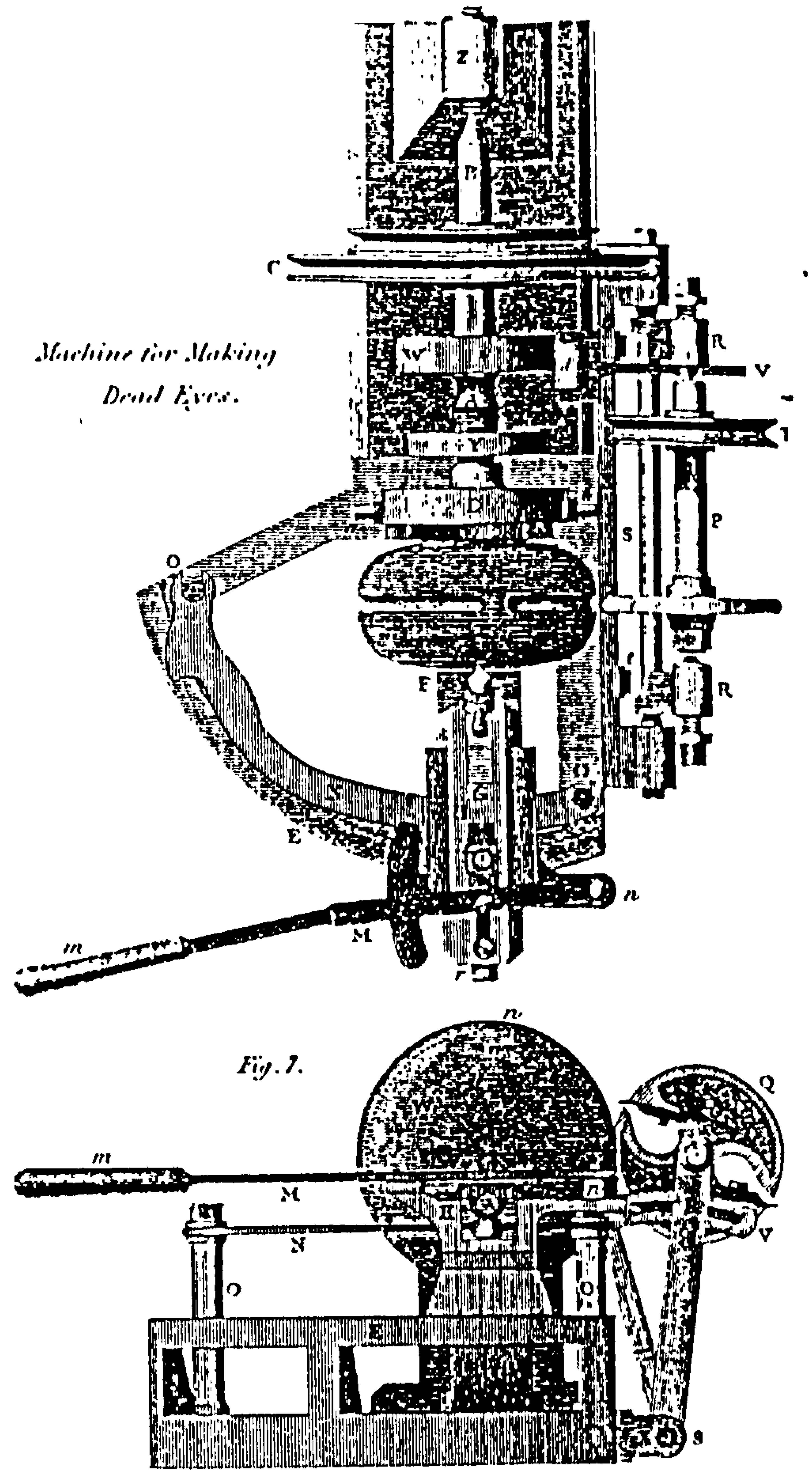


Fig.18. Brunel's Machine for Makin
Dead Eyes c.1805
(Reec's Cyclopedia 1819)

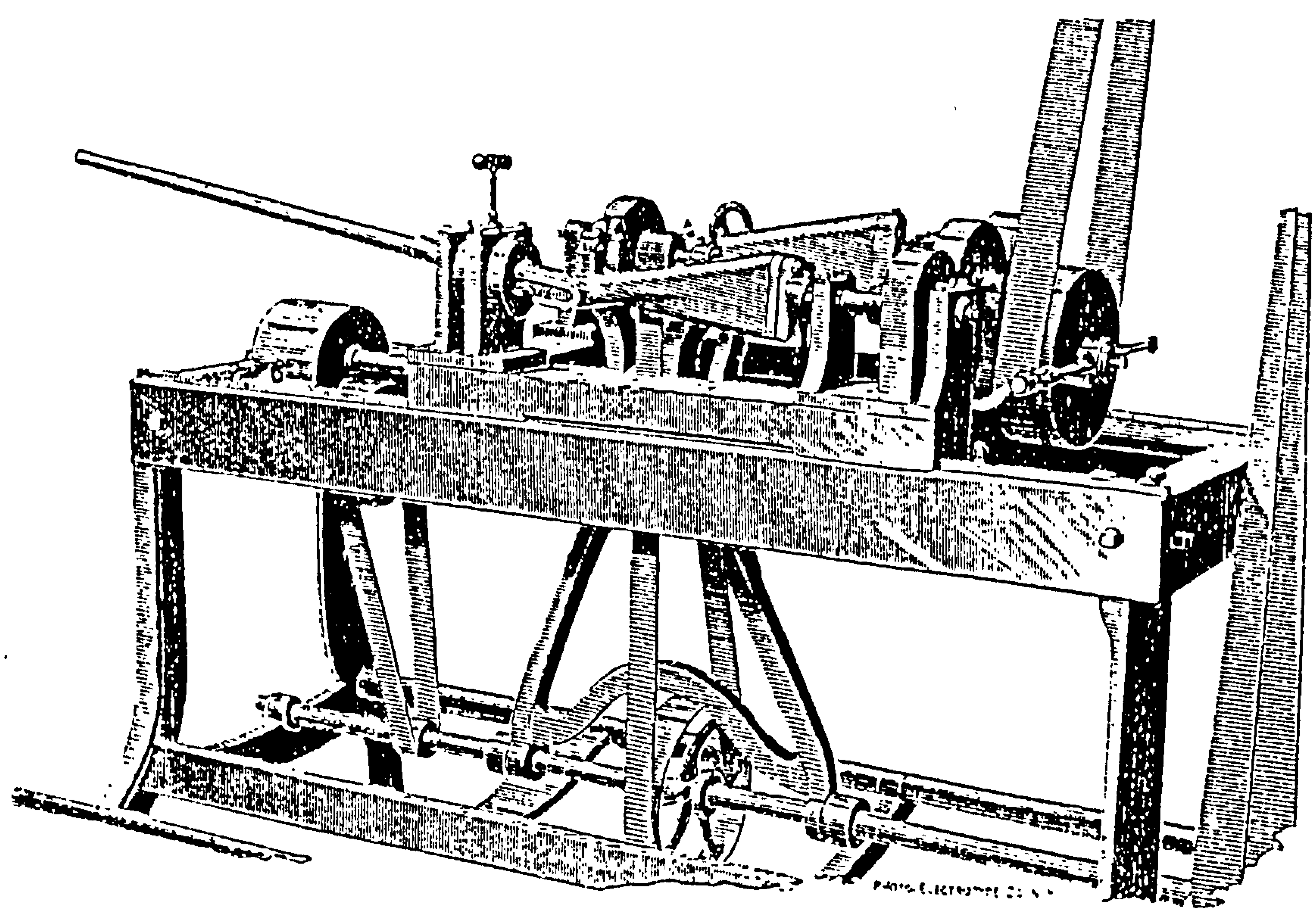


Fig.19. Cyrus Buckland's Improved Blanchard Lathe c.1854
(Fitch Census Report 1882)

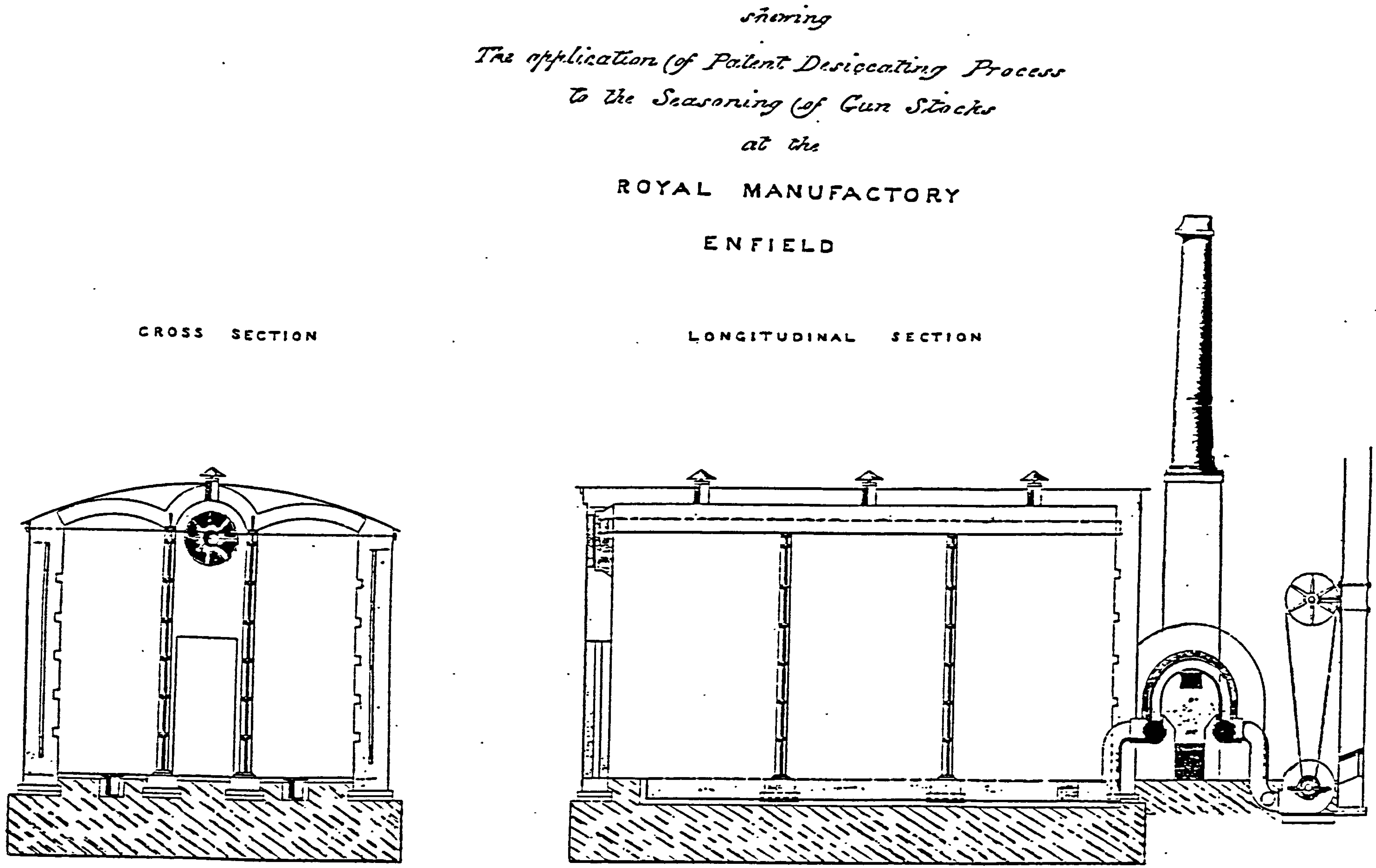
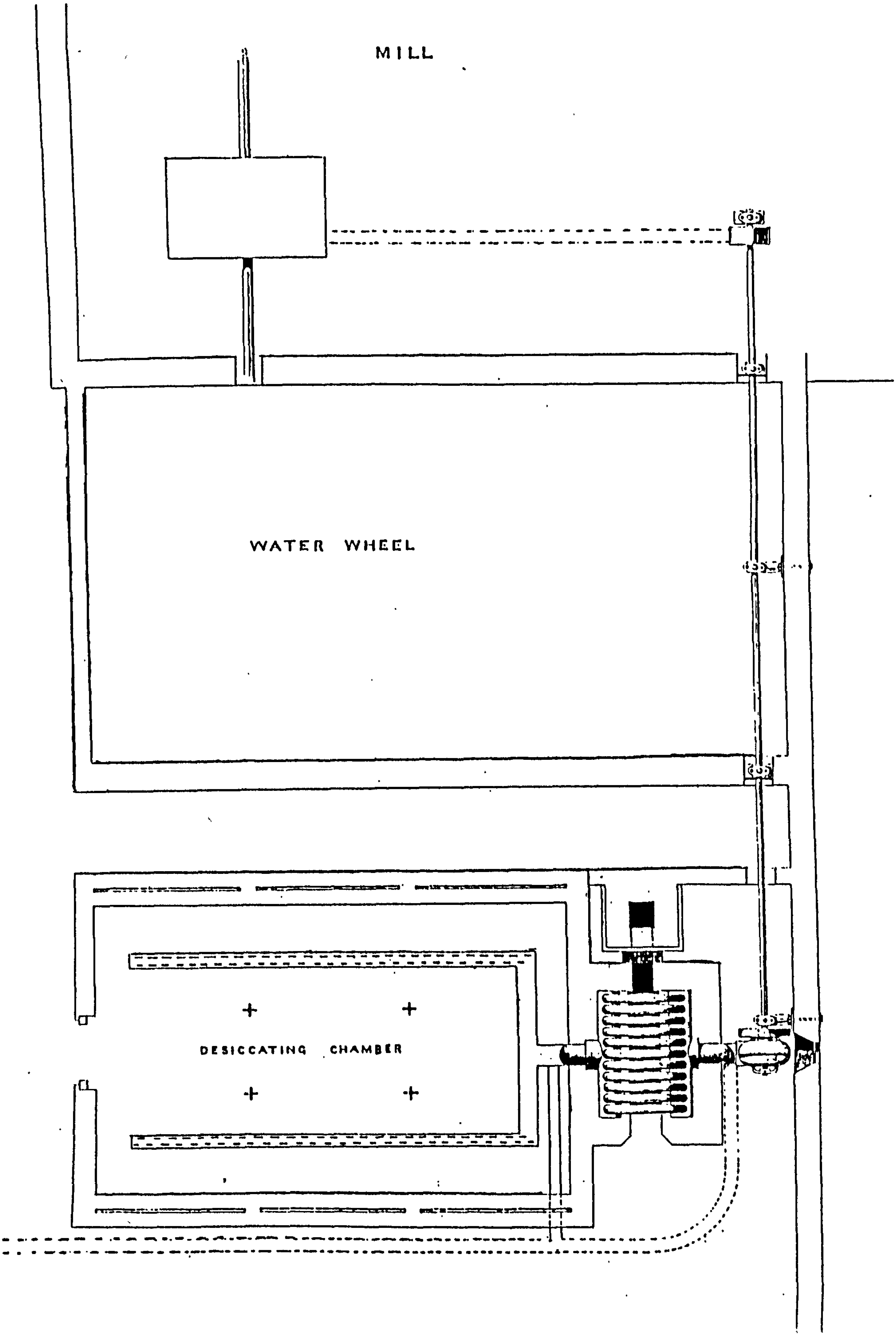
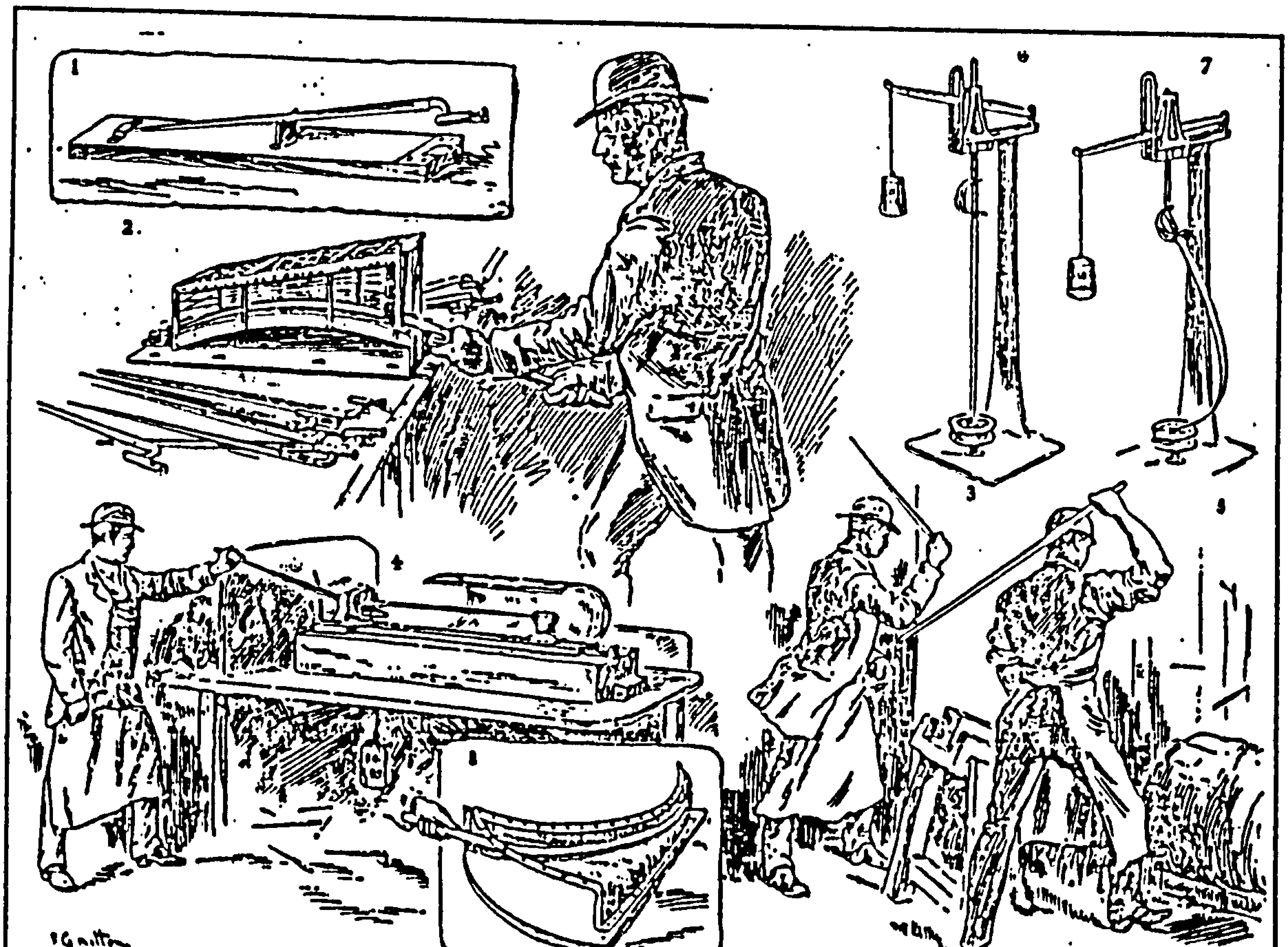


Fig.20. Davis & Syimington's Patent Process - Gun Stock Seasoning Chamber c.1848 (Public Record Office WO44/644)

Fig.21. Davis & Syimington's Patent Process - Gun Stock Seasoning Chamber c.1848 - Fan Drive Mechanism from Mill Wheel (Public Record Office WO44/644)





1. The "Bridge" Test (old style) for Triangular Bayonets
2. The "Curve" Test (the method adopted during the last two years)
3. The "Striking" Test for Bayonets
4. The "Twisting" Test for Bayonets
5. The "Striking" Test for Cavalry Sword Blades
6. The "Vertical Pressure" Test for Cavalry Swords (A weight of 33lbs. must not deflect the blade)
7. The "Vertical Pressure" Test. (A weight of 40lbs. must shorten the length of the blade by six inches without breaking it)
8. The "Curve" Test for Sword Blades

Fig.22.Bayonet and Sword Testing - c.1850

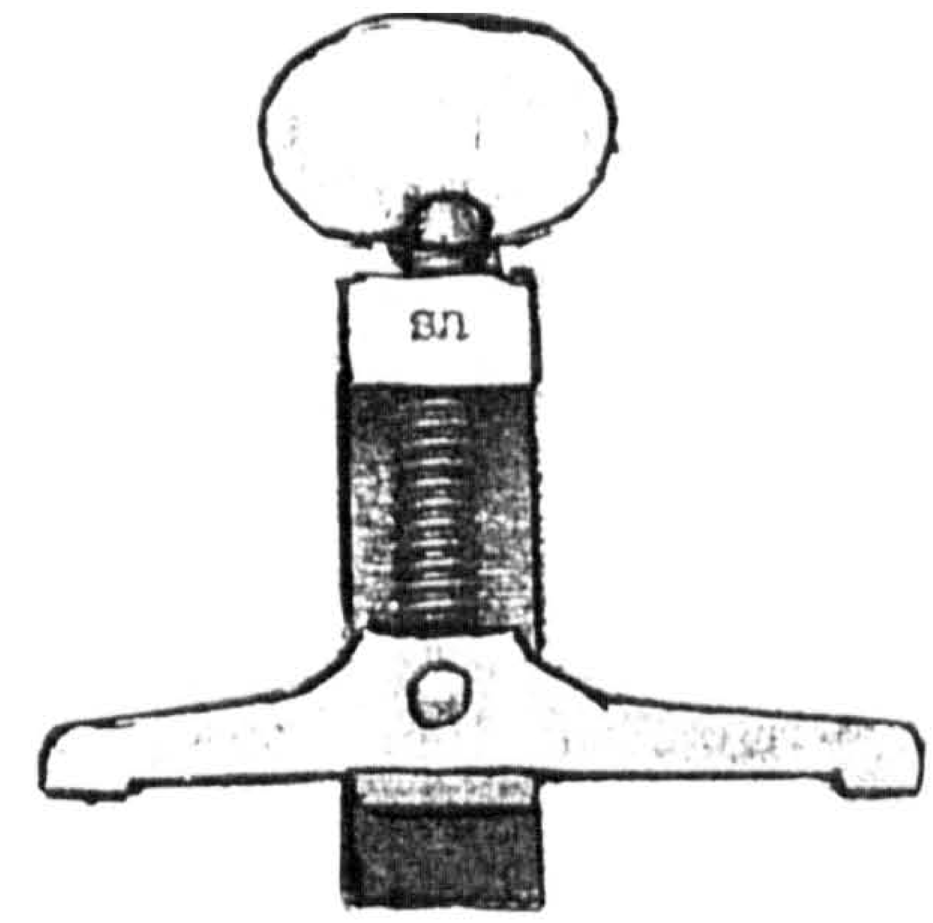


Fig.23. U.S. 1855 Main Spring Cramp (Vise), for M1842 musket and conversion muskets. (Gun Tools: Their History and Identification)

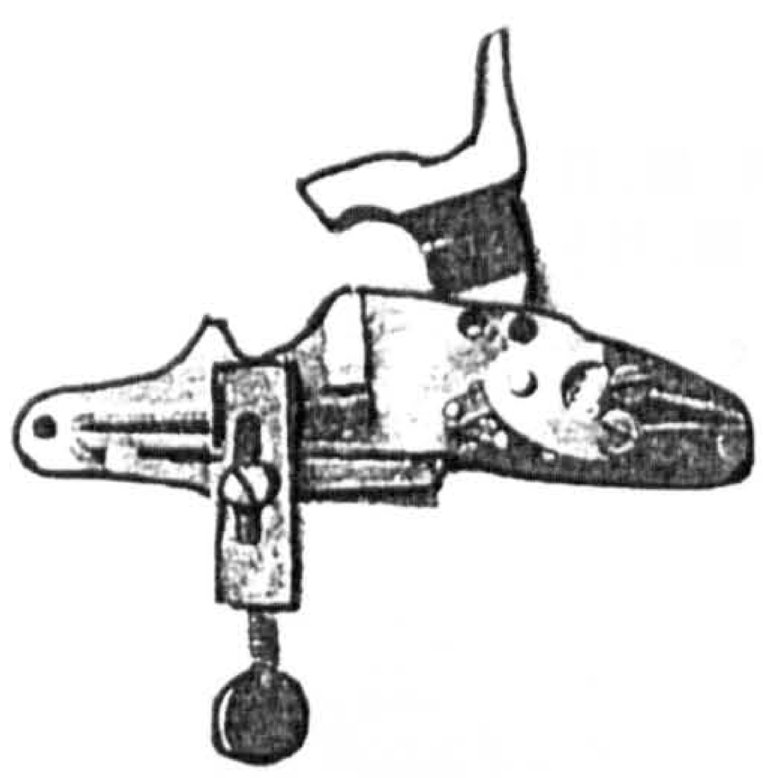


Fig.24.
Main spring cramp tightened.

Fig.25.
Main spring removed.

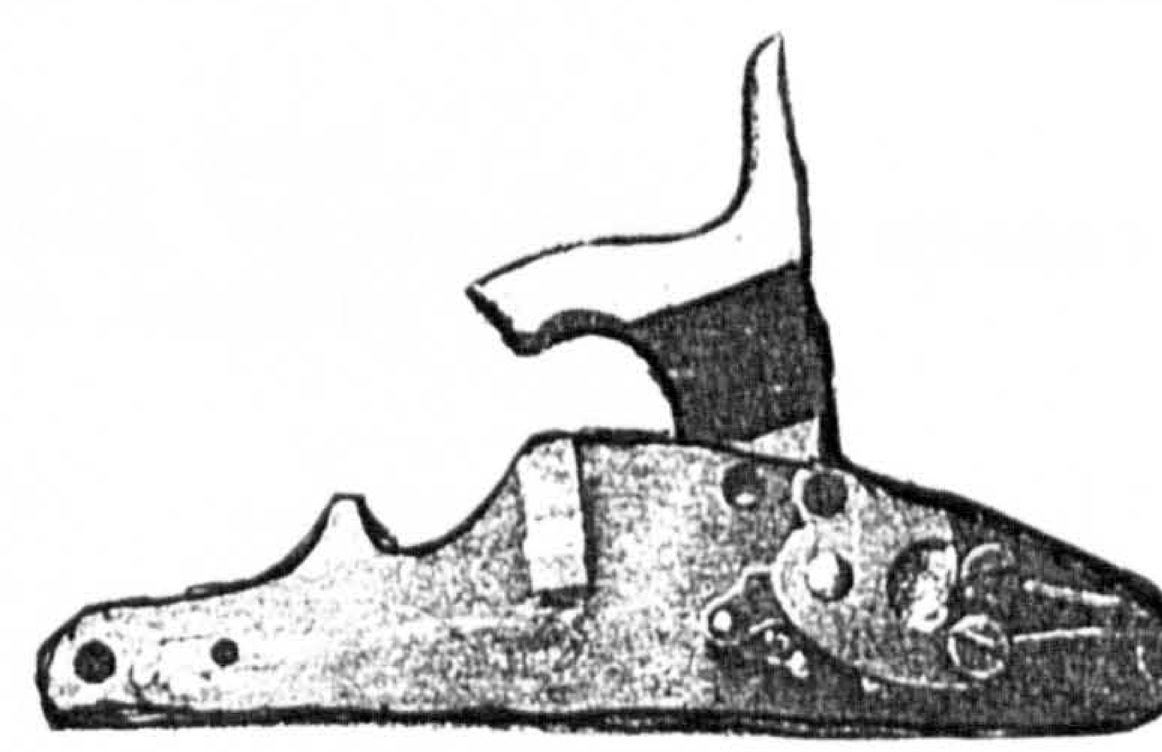


Fig.26.
Lock mechanism showing main spring removed.

(Gun Tools: Their History and Identification)

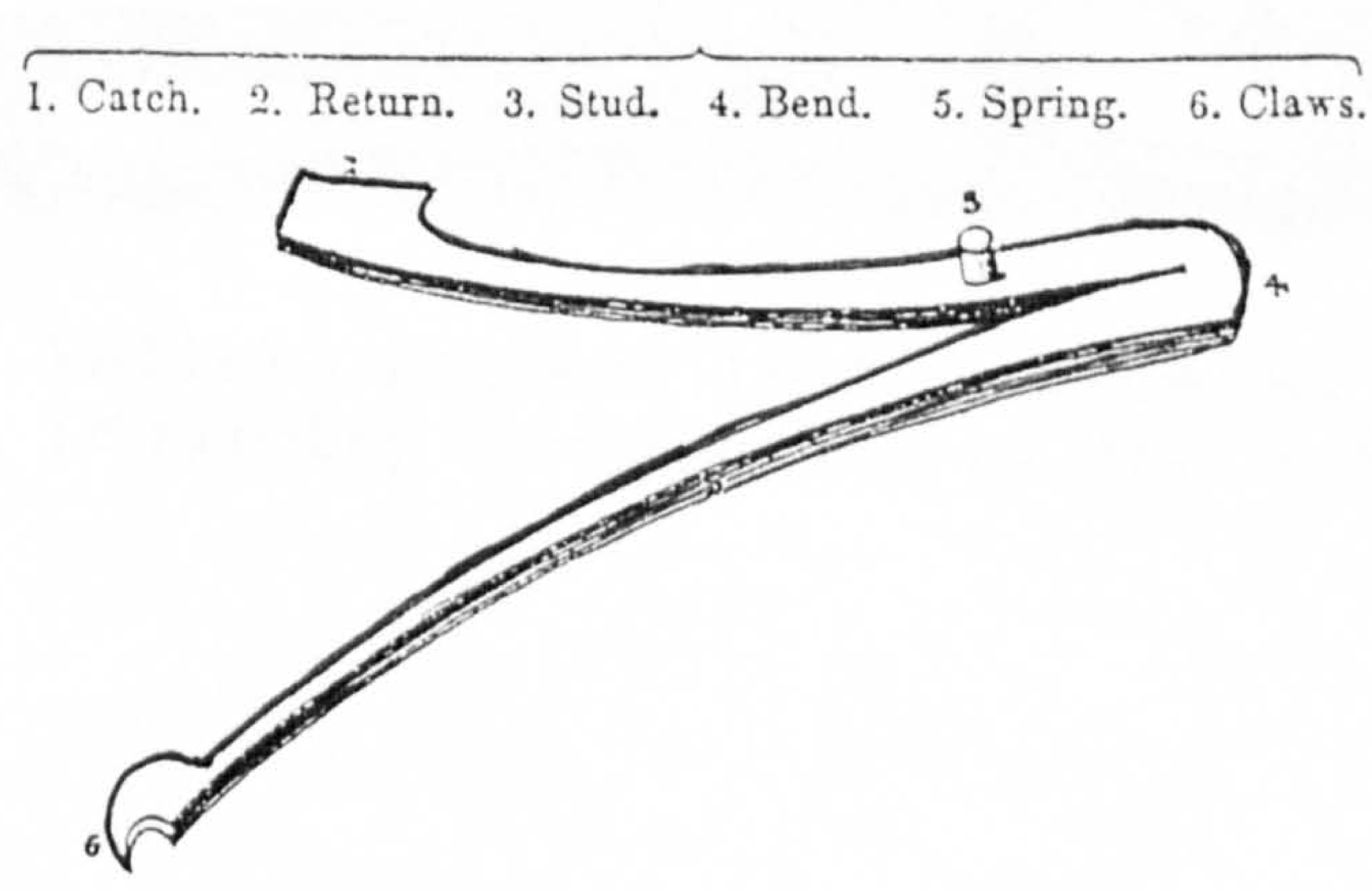
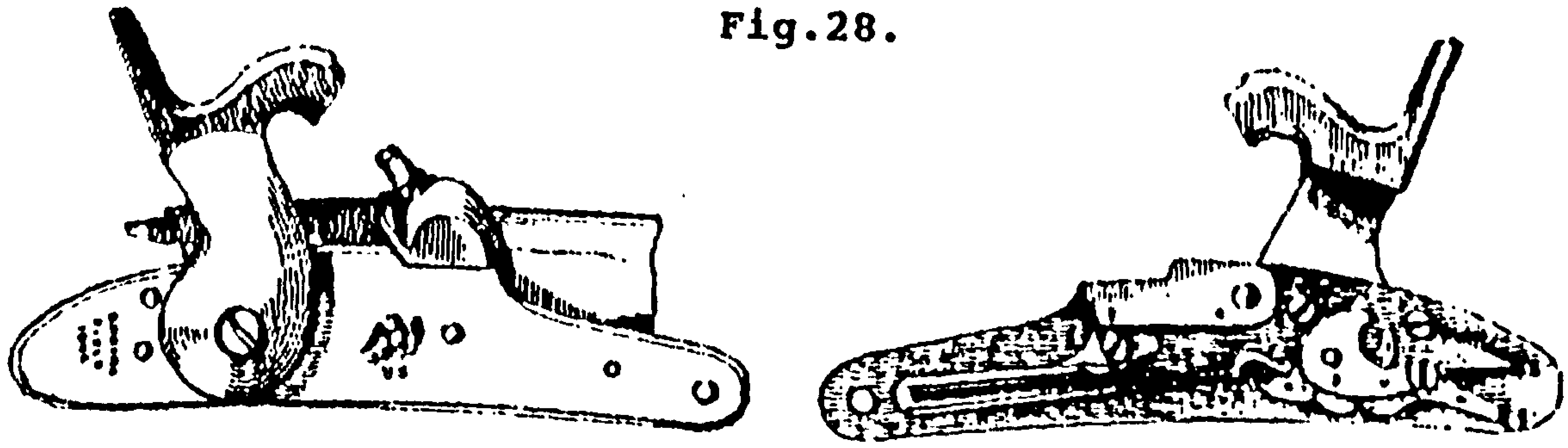


Fig.27. Enfield Pattern 1853 main spring
(Musketry Instruction of the Army, 1864)

Fig.28.

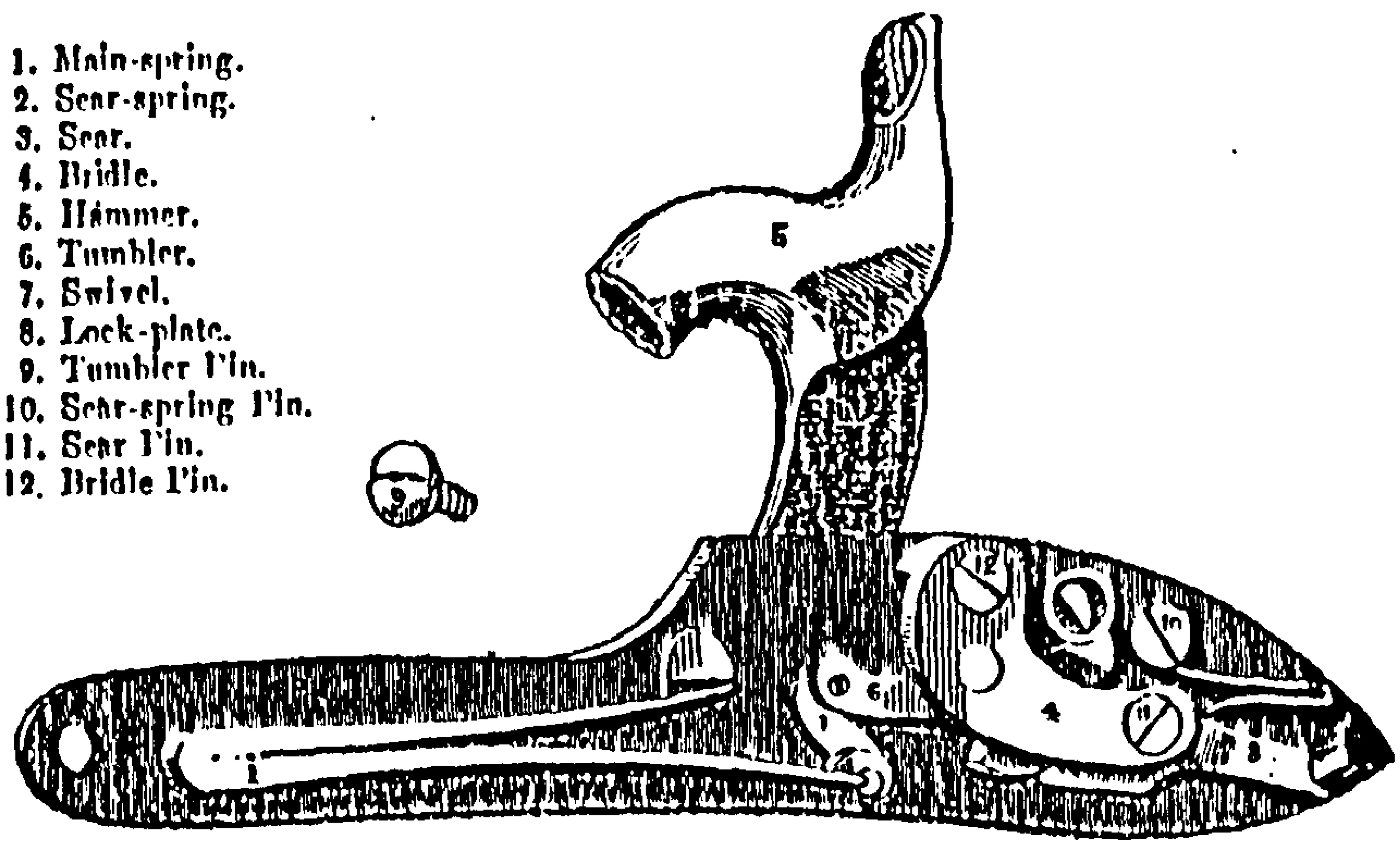


U.S Musket Model 1842 percussion lock
(U.S Military Firearms 1776-1956, Major James E Hicks)
(Illustrated by Andre Jandot)

THE LOCK

The limbs to be named in the order in which they are removed, viz. :—

1. Main-spring.
2. Sear-spring.
3. Sear.
4. Bridle.
5. Hammer.
6. Tumbler.
7. Swivel.
8. Lock-plate.
9. Tumbler Pin.
10. Sear-spring Pin.
11. Sear Pin.
12. Bridle Pin.



Enfield Pattern 1853 percussion lock
(Musketry Instruction of the Army, 1864)

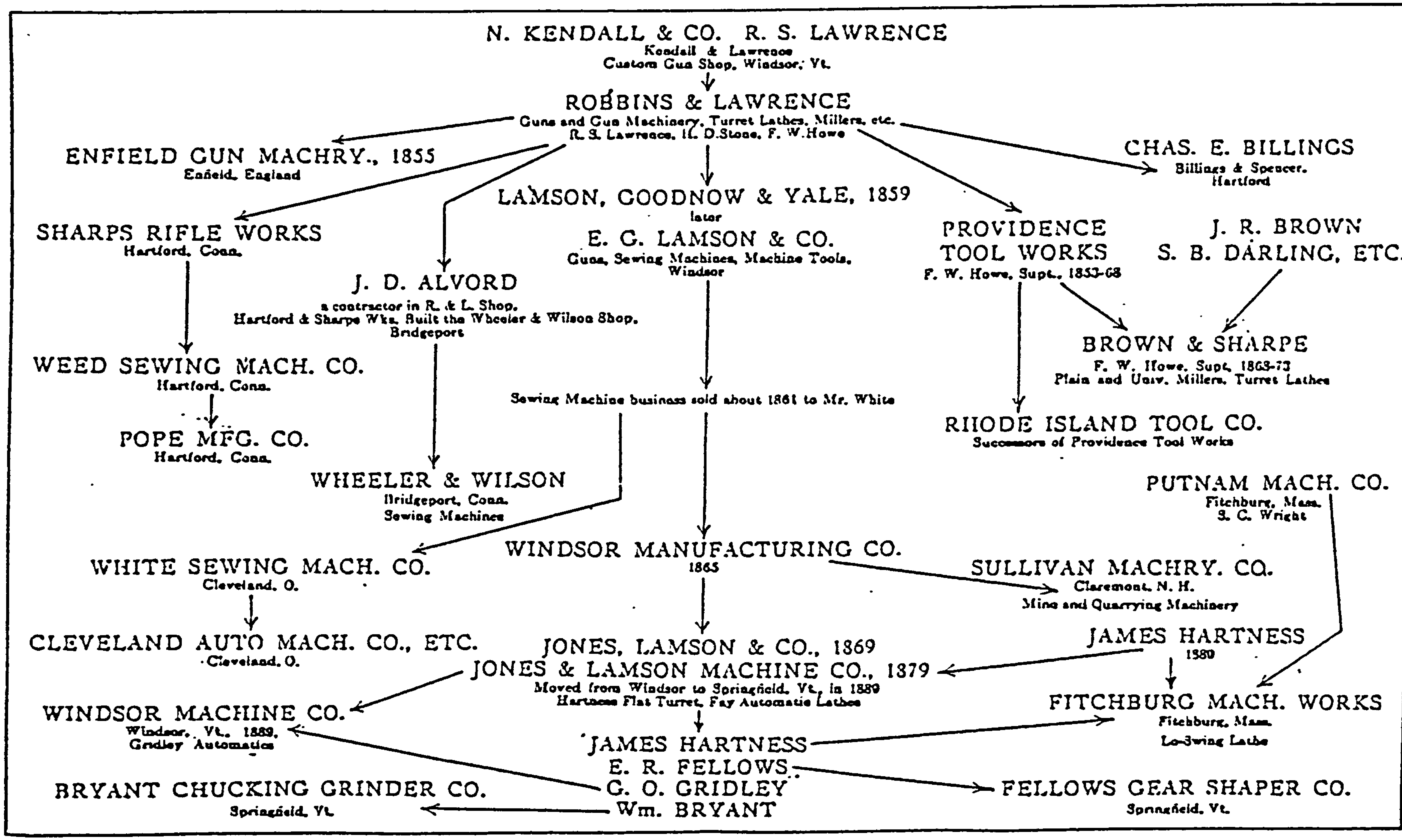


Fig.29. Joseph Wickham Roe's Genealogy of the Robbins & Lawrence Shop

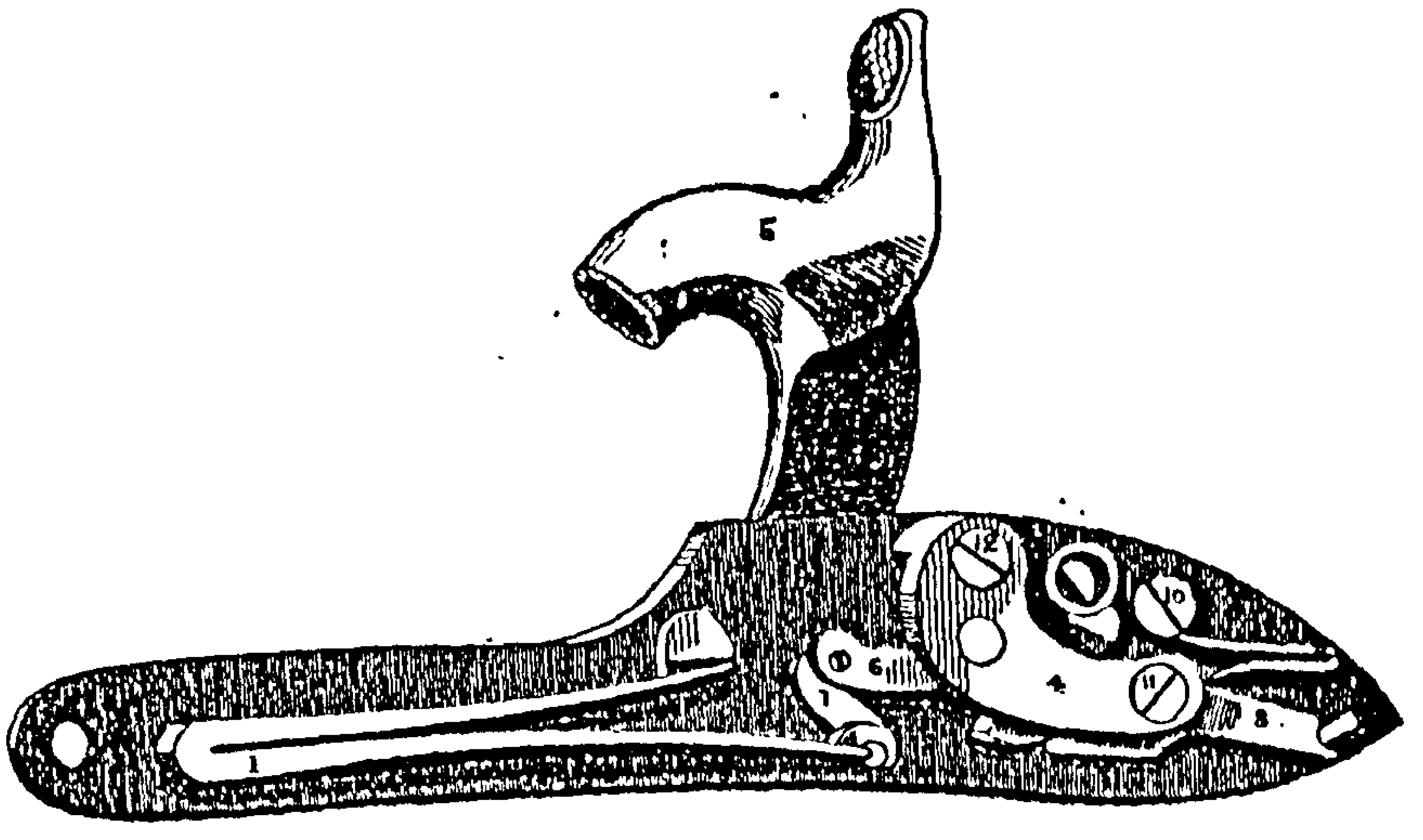


Fig.30. Enfield Pattern 1853 lock. Note the curve running down the back of the hammer head and extending below the head area as viewed from the rear of the mechanism.

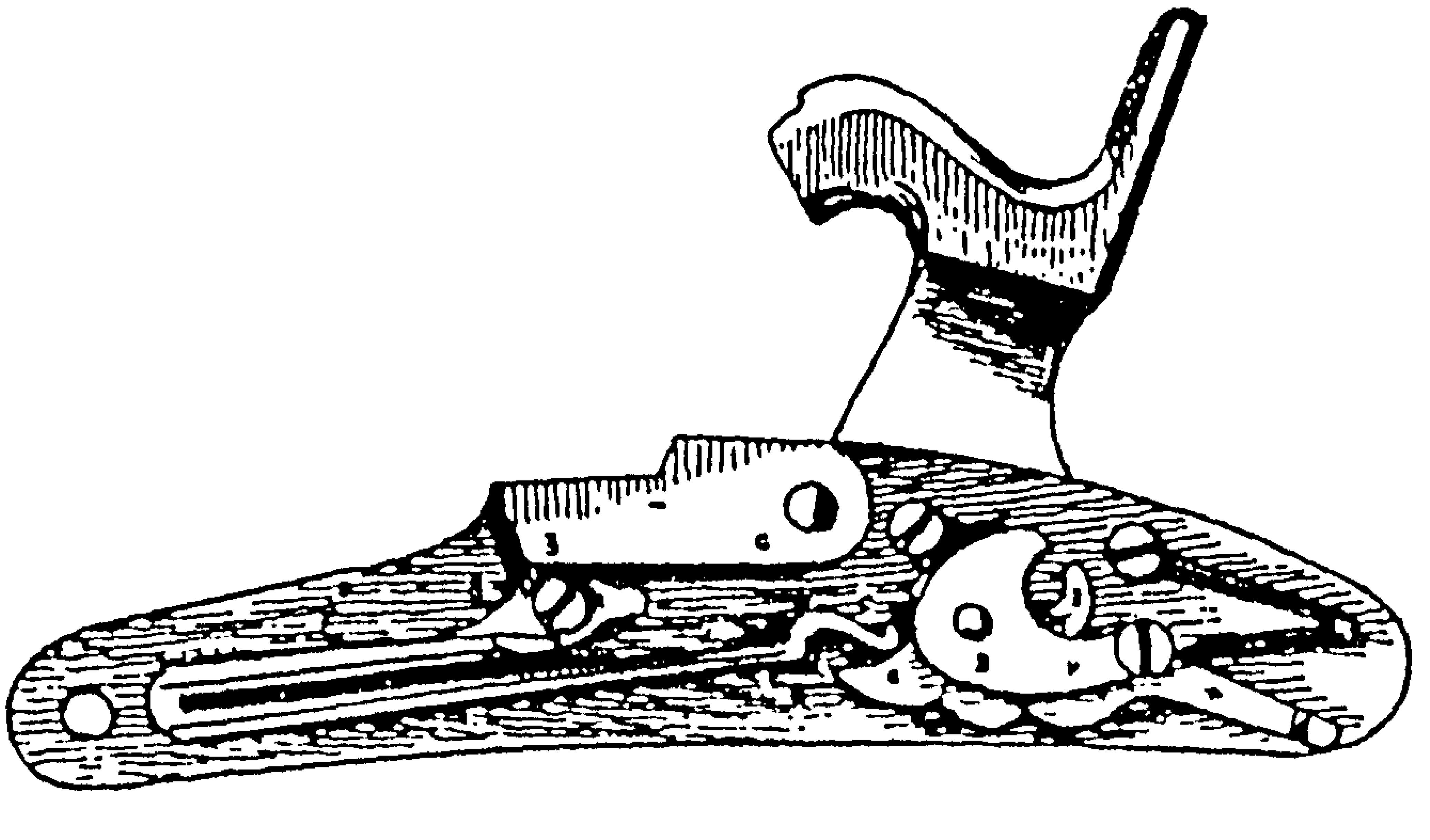


Fig.31. United States Army M.1842 lock. Note the straight line down the back of the hammer head. Also note the simple straight area below the head compared to Fig.30.