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Reinventing Warfare 1914–18

Novel Munitions and Tactics of Trench Warfare

Anthony Saunders

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Acknowledgements

This book has its origins in a chance discovery I made in 1978 when working as a Patent Officer in the Principal Directorate of Patents at the Ministry of Defence. While searching the patent abridgements for Class 119, small arms, covering 1915–16, I was surprised to discover patents granted for grenades and other devices for trench warfare. These included the first patents granted to William Mills for the grenade which came to known as the Mills bomb. Until that point, it had not occurred to me that such things would have been patented.

In 1997, I set about researching the field of novel munitions invented for trench warfare and, in 1999, *Weapons of the Trench War* was published by Sutton Publishing, followed by its companion, *Dominating the Enemy*, in 2000. The former dealt with the invention and development of grenades, mortars and flamethrowers during the First World War, while the latter dealt with body armour, periscopes and wire-cutters. These were the first serious studies in this field. The invention and widespread use of such devices on the Western Front led me to speculate on their effect on tactics. With that in mind, I embarked upon a PhD to investigate the invention and use of trench warfare munitions by the British on the Western Front. This book emerged from my doctoral thesis. As far as I am aware, this is first work of its kind. No other work has been undertaken by any scholar to examine the relationship between the technicalities of a munition and the tactics of its use. Thus, this book has a technical content as well as an examination of tactics at the small unit level. And it bridges the gap between these two rather different disciplines with an examination of the infrastructure that had to be created to devise, develop and mass produce these novel munitions.

Any project of this scale inevitably requires the assistance of others. I would like to thank everyone who has helped me with this project over the years.

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This book is the culmination of many years work and I am grateful to everyone who has assisted me along the way. If I have to omitted to mention anyone, I hope they will forgive me as it is no reflection on their contribution to this project.

Introduction

No army went to war in 1914 expecting to conduct trench warfare for four years and, consequently, no army was equipped for such an eventuality.[1] Apart from the demands for howitzers, large-calibre guns and huge quantities of high-explosive shells, trench warfare also required other sorts of munitions. The British described these as novel or experimental to distinguish them from conventional weapons.[2] The challenge of providing the British Expeditionary Force (BEF) with devices to enable the infantry to conduct trench warfare operations on the Western Front has attracted little attention since the 1920s and 1930s when it was discussed during some of the hearings conducted by the Royal Commission on Awards to Inventors.[3] Indeed, there has been scant acknowledgment since then that the War Office and the BEF faced an enormous problem which required unconventional solutions. Thus, the question of whether this challenge affected the conduct of BEF operations on the Western Front has not been adequately discussed hitherto, whereas the tank, defences in depth, infiltration tactics and the development of artillery tactics in the evolution of deep battle have all attracted much scholarly analysis.[4]

The war on the Western Front was principally an artillery war.[5] While novel trench warfare munitions played a significant role in the development of British infantry tactics, which, themselves, were part of the evolution of three-dimensional warfare, artillery was the dominant force on the battlefield, both in attack and in defence. However, the contribution of novel munitions has been largely overlooked in studies of the evolution of warfare. Such munitions were principally hand grenades, rifle grenades, trench mortars and their ammunition. Hitherto, historians have tended to assume that these munitions were incidental to the development of warfare. Indeed, there has been an assumption that they were merely copies, or minor developments, of similar devices improvised during the Russo-Japanese War.[6]

Such assumptions ignore the fundamental changes which occurred within the infantry of the British Army during the First World War. Such changes were directly related to the adoption of novel munitions on a scale exponentially greater than anything experienced by the Russians or Japanese in Manchuria a few years earlier. The nature of infantry, how it was armed and how it fought, was fundamentally changed by these munitions during the First World War. Indeed, the infantry of 1918 and thereafter was quite unlike the infantry of 1914.[7] This was especially true of the BEF but the effect was universal and no army emerged from the First World War unaffected by trench warfare munitions. Rather than being merely another technological advancement in the engines of war due to the inevitable march of progress, however, the transformation in the infantry was brought about by a process of change different from that usually discussed in relation to technology and warfare. This book discusses the relationship between technology and tactics and shows how warfare was changed by the invention of novel infantry munitions.

To understand this process, an appreciation of the technical aspects of these devices is essential. An examination of the technicalities of a technology is not commonly applied in an historical context. Yet, the technical characteristics of these trench warfare devices played a crucial role in the process of change. The problem, of course, is how to deal with the technicalities from an historical perspective, a conundrum that is far more complex than it might at first appear. Here, we cannot be solely concerned with design. The way in which such devices functioned is at the heart of the process of change because functionality goes to the heart of the tactical developments. While tactical change depended upon functionality, this was not a case of a new technology overwhelming outdated munitions. On the contrary, this was a case of increased functionality leading to technical reliability which, in turn, allowed the development of new tactical doctrines. These changes were directly related to the technical characteristics of the munitions concerned. Hitherto, the relationship between the technical and the tactical has not been examined, and certainly not from a technical perspective in an historical context.

Function rather than form is the crucial element here, although the two have a direct relationship. The manner in which something is *intended* to function, as defined by its mechanical characteristics, is of greater significance than the form or appearance of the device in question. The difference between intention and actuality is important in this context as it highlights the role of failure in the processes of invention and development, an aspect of technology which is rarely considered in relation to change. The process of invention in the context of these munitions sheds light on functionality which itself was fundamental to tactical change.

At the outbreak of war, the BEF possessed no trench warfare munitions because no one in government or the War Office had foreseen a need for them. The munitions did not exist and had to be invented.[8] The concept of invention as a process and, indeed, the matter of what constitutes an invention – the product of such a process – is not generally discussed in books which deal with military history. Nevertheless, invention goes to the heart of the changes which occurred in the British Army during the Great War.

Invention was fundamental to the provision of what the BEF needed. The backgrounds of the inventors helped to determine the nature of their inventions. The inventors were mostly civilian engineers who had a different ethos from those engineers usually concerned with developing munitions. Because such munitions did not exist prior to the war, no specification for them existed. This raised questions about the form they ought to take and how they ought to function.[9] These inventors were not constrained by what may be termed conventional armament design considerations because they had no experience of munitions. Thus, they relied upon first principles, that is, basic engineering principles. Conceptualization of these devices came afterwards. Tactical developments followed invention rather than concept.[10]

Thus, invention affected the development of tactical guidelines for the operational use of these munitions. The question of how such munitions should be handled in the field, how soldiers should be trained in their use, indeed, how the munitions should be used operationally and tactically, could only follow after the devices had been invented and developed, while their technical characteristics defined the tactical limitations. There was no body of knowledge on procedures and tactics prior to their invention.[11]

What tends to be overlooked is the fact that, in 1914, no infrastructure existed for the organization of the manufacture and supply of these munitions.[12] Thus, an examination of the organizational and logistical problems, and their solutions, as well as an examination of the processes of evaluation of inventions are important elements in this story. An unusual set of circumstances existed during the First World War which provided fertile ground for the kind of change which occurred. The fact that every aspect of the provision of novel munitions for trench warfare had to be created from scratch has not been fully acknowledged before now.[13] As will become clear, the manner by which this was achieved played a crucial role in the evolution of infantry warfare.

Invention is but one of a complex series of processes which make an idea tangible, then take a prototype and turn it into a mass-producible device. The manufacturing processes had to be devised and carried out by engineering firms unfamiliar with the demands of munitions production, a considerable achievement in itself. The firms and the processes had to be organized and the manufacturing monitored by a process known as inspection (in modern parlance, quality assurance).[14] The inspectors had to be trained and organized. Large-scale manufacture of these munitions created a huge organizational and logistical challenge but, at the same time, raised engineering standards by increasing the level of skill in the workers involved in the fabrication of these munitions.[15] Innovative solutions to the problem of quick and reliable manufacture had to be found. The mass production of munitions by such firms was a contributory factor in the development in Britain of a fully industrialized approach to the war. These solutions were directly related to the technicalities, in both mechanism and form, of the munitions concerned. Some designs were modified to accommodate new mass-production techniques.[16] Design and manufacture bore directly on handling procedures in the field and, hence, on tactics and operations.

The problems associated with invention, conceptualization and manufacture had to be handled concurrently with the problems of operational usage and training, which compounded the difficulties. This unusual circumstance was caused by the urgent need for such munitions.[17] The situation during much of the First World War was an inversion of normal peacetime practice and experience.[18] Ideally, such matters were handled sequentially, allowing a straightforward feedback loop. However, urgency precluded this, so that the processes of invention, development and manufacture were neither simple nor smooth. Inevitably, conflicting ideas about the nature of these munitions remained throughout the war.[19] However, by 1918, they had ceased to be regarded as novel and had become standardized equipment. *Reinventing Warfare* examines how this came about.

The wartime circumstances required adept problem-solving skills and ad hoc solutions rather than rigid procedures in order to solve problems quickly. This was especially true of the first eighteen months of the war when shortages were especially acute. The significance of this was not lost on some of those who were responsible for providing novel munitions.[20] However, it has tended to be missed by historians who usually regard the lack of grenades and mortars as mismanagement, criticizing the War Office for inefficiency.[21] Such views are based on poor understanding of the problems faced by the War Office and by industry, how they were addressed and, indeed, the process of invention.

Expediency during the first year of trench warfare dominated how all matters pertaining to novel munitions were addressed. The unrelenting demands for such munitions throughout the war ensured that a sequential execution of these processes never fully developed. Before the war, expertise in these areas did not exist in any government department nor in any branch of the British Army. Expertise had to be acquired which meant that sometimes mistakes and compromises were made. The solutions required men with open minds and the ability to recognize novelty if the BEF was to be provided with what it needed for trench warfare operations. The only soldiers with any kind of familiarity with unconventional munitions were Royal Engineers but their knowledge was empirical, ad hoc, and far from universal within the service.[22] Thus, every aspect of providing novel munitions and the manner of their use, operational and tactical, had to be learned and as quickly as possible.

This, then, was the extent of the challenge which faced not only the BEF but also the British government and British industry at the start of trench warfare on the Western Front in the autumn of 1914.

There is no single narrative thread which commences at a beginning that coincides with the start of trench warfare and continues unbroken to an end that coincides with the return to mobile open warfare during 1918. Rather, there is a series of concurrent narratives. These may be defined as: the conceptualization of novel munitions; the bureaucracy and organization of the invention, development and supply of novel munitions; the technical evolution of novel munitions; the improvement of operating procedures and the growth of training; and the advancement of tactics. These narratives were not independent of each other, of course. Indeed, their inter-relationships were complex. This book is organized along these lines for the sake of convenience rather than because such a demarcation actually existed. In so doing, the complexity of the provision and employment of novel munitions for the infantry is, hopefully, made clearer.

The munitions which are the subject of this book were not the only novel devices of the war. Novel weapons also featured in the air war and in the war at sea.[23] Moreover, as far as manufacturing capability and logistical support were concerned, many of the other novel devices competed with hand grenades, rifle grenades, trench mortars and their ammunition for production capacity. As far as trench warfare was concerned, other novel munitions included body armour, periscopes and hyposcopes, bomb-throwing engines, wire-cutters, flamethrowers and the Livens projector, a form of mortar used in gas warfare.[24] These devices are outside the scope of this book although many were indispensable to trench warfare. The periscope, in particular, was of vital importance. Periscopes were needed in large numbers by the artillery as well by the infantry. While the artillery took precedence over the latter for good-quality magnifying periscopes, without the lower-quality instruments with which the infantry had to make do, the front-line infantry would have been largely blind.[25] The British devised and used more forms of body armour than any other combatant nation during the First World War.[26] It was from so-called mobile or wheeled shields that the tank emerged.[27] Mechanical bomb-throwing engines and catapults were widely used as substitutes for trench mortars while the latter were in short supply – until about the spring of 1916.[28]

However, while these other devises were important to trench warfare, widespread use of reliable grenades and mortars led to tactical change while the other devices did not. Although gas weapons were conceived for trench warfare, they are outside the scope of this book, which is solely concerned with infantry weapons and tactics. Gas weapons, including the Livens projector, were operated by the Special Brigade,[29] Royal Engineers. Moreover, gas warfare is too vast a subject to be included here and has been well, if not comprehensively, covered elsewhere.[30] The tactical use of gas weapons was unique to such weapons although similar in some respects to the use of artillery.[31] While the tank was conceived as a means by which the deadlock of trench warfare might be broken, it is not part of this book. The tank did not appear on the Western Front until September 1916 and was operated by a specialist unit, the Tank Corps. The development of the tank and its role during the First World War has been well covered elsewhere.[32]

An essential question which needs to be addressed is whether the novel munitions under discussion here had precursors from earlier wars, in particular, the American Civil War and the Russo-Japanese War. Did any device prior to the outbreak of war in 1914 anticipate the trench warfare munitions devised during the First World War? To assume that the trench warfare munitions of the First World War were derived from earlier similar-looking devices is an enormous leap of faith. Indeed, examination of the engineering evidence suggests otherwise. Yet, historians make such an assumption about First World War grenades and mortars. This is largely because the engineering evidence is not examined. A further assumption is that all grenades and mortars were essentially the same when, in fact, the novel munitions provided to the BEF during the First World War had no antecedents and were different from other Allied or German devices. Not only was an inventive step involved in the creation of the unconventional munitions employed by the BEF but there was effectively no prior art.

The question of whether technological change occurs as a series of logical next steps or whether it involves inventive leaps is pertinent to the discussions in this book. An examination of objections raised by Patent Office examiners during the process of obtaining a patent for an invention provides some insight.[33] Generally, such objections are of three types: that the invention is entirely anticipated by the prior art and, hence, not an invention at all; that the prior art anticipates certain aspects of the invention but does not anticipate it is in entirety so that some elements of the invention are inventive but not all; or that the prior art merely *seems* to anticipate the invention so that the invention is, indeed, entirely new. In the last situation, a reasoned argument can be constructed to demonstrate that the prior art does not, in fact, anticipate the invention. There is, of course, a fourth possibility: the invention is not anticipated. It follows, then, that, if technological change occurs as a linear progression of logical next steps, situations three and four cannot arise. Previous writers on the subject of technological change, especially in the context of warfare, have tended to follow the logical next step model, viewing inventive leaps as the exception to the rule.[34]

What has been written about the grenades and mortars and where do they figure in the literature on the First World War? This is not merely a matter of placing the subject in the context of existing scholarship but it is also one of putting the questions which this book attempts to address, as discussed above, into the context of those which have already been asked about trench warfare. Indeed, it becomes apparent that the questions which this book addresses have not actually been posed hitherto, partly because invention, both as a process and as a product of that process, tends to be viewed as the inevitable consequence of the march of progress. The role of failure in this process is often underplayed, misunderstood or ignored in the literature. Surprisingly little has been published about the novel munitions of trench warfare although they do, inevitably figure in a great many books about the First World War. Unfortunately, few of these books are reliable as they tend to repeat the same assumptions and fail to examine the engineering evidence. No book, contributed chapter, paper nor journal article correlates the technical aspects of any of these devices with operational or tactical usage during the First World War.

It is fair to say that the field of novel munitions for trench warfare has been under-researched. Prior to the research undertaken for this book little of the archival material concerning these munitions had been examined in detail. There are several hundred files in the National Archives pertinent to this field, most of them in the Ministry of Munitions (MUN) series, the majority in the MUN 4 series and MUN 5 (historical record) series but files also fall in the War Office (WO), Treasury (T), Treasury Solicitor (TS), Board of Trade (BT), Cabinet Office (CB), Supply (SUPP), and Directorate of Scientific and Industrial Research (DSIR) series. Of the Treasury files, the most relevant to this field are those in the T 173 series which contain records of the proceedings by the Royal Commission on Awards to Inventors, which sat during the 1920s and 1930s to hear claims submitted by inventors in respect of government use of their inventions in the pursuance of the war. The T 173 series also contains verbatim records of interviews of expert witnesses called to give evidence both for and against the claimant. There are some 830 files in this series but only twenty-five are pertinent to this study. These records provide valuable insights into how inventors worked and the importance of their inventions to the conduct of the war. T 173/1 and T 173/26 contain material concerning the procedures adopted by the Royal Commission and the procedures for appointing members of the Commission.

Material relating to William Mills and to Henry Newton, two inventors of considerable importance, comes from private papers.[35] [36] Information about the activities of the Royal Engineers in relation to inventions and the manufacture of novel munitions is problematical because there appear to be no extant primary sources. Most information concerning the Royal Engineers and their involvement with novel munitions is contained in a series of articles published in *The Royal Engineers Journal* between 1924 and 1925. There appears to be no archival sources extant relating to the Army Workshops or to the Experimental Section, GHQ, all of which played important roles in the processes of invention, evaluation and manufacture of novel trench warfare munitions. The war diaries of the Army Workshops during 1915, one of the most important years for the invention and manufacture of novel trench warfare munitions, were lost during the Great War, probably during the German spring offensives of 1918.[37]

A wide range of official documents concerning operating procedures, tactics, training, lessons from recent fighting, and technical developments were published both in Britain and by GHQ as official documents in the Stationery Service (SS) series.[38] These not only include SS135 and SS143 and other tactical manuals but also technical and procedural manuals concerning grenades and mortars. These all provide essential information about the way in which such munitions were used on the Western Front. They are all the more important because they were derived from both the technical characteristics, and limitations, of the munitions concerned and practical experience of their use in the front line.

The relationship between what was printed in the manuals and what occurred in practice is one which is difficult to quantify. The two principal sources of what occurred in practice are war diaries and memoirs. Examination of these might seem to offer insights into tactical and procedural issues. This presupposes that tactical developments in grenade and mortar warfare were from the top down and based upon theory rather than derived from experience; in fact, they arose from experience on the battlefield allied with an understanding of the technical characteristics of the devices in question.[39] Moreover, war diaries tend not to include tactical information relating to grenades although the diaries of trench mortar batteries do offer some insight into operational use of mortars. However, a very large number of mortar battery diaries would need to be examined to allow meaningful analysis and time did not permit this.

British patents published between about 1900 and 1925, and the patent abridgements for the period 1855 to 1930, are essential primary sources. Patents are a valuable resource of historical technical information, both individually and collectively. They explain how an invention is intended to work and often discuss the problems which the inventor was attempting to solve. By referring to the patent specifications, it is possible to conduct a comparative technical analysis of some of the more important munitions. Collectively, patents provide information about the inventors and their market position: the more patents an inventor has been granted in a given field, the greater his hold on that field, especially from a commercial perspective.[40] The patents classification system of the time allowed the abridgements to be grouped according to subject, independent of the patent number.[41] The Classes at the time of the First World War pertaining to the novel munitions under discussion in this book are: 9 (i) ammunition and ammunition receptacles; 9 (ii) torpedoes, explosives and pyrotechnics; 92 (i) ordnance and machine-gun carriages and mountings; 92 (ii) ordnance and machine-guns; and 119 small arms.

Reinventing Warfare fills a gap in the scholarship of the First World War. It has three principal objects: first, to examine the processes by which novel trench warfare munitions were invented and developed into manufacturable devices, then supplied to the BEF; second, to examine the relationship between the technical characteristics of these devices and the evolution of tactics for their use on the Western Front; and, third, to consider whether the technical characteristics of specific novel munitions had a direct effect upon operations and tactics. The mechanism by which the latter occurred and its applicability to technological change in relation to changes in warfare form part of the discussion.

In addition, *Reinventing Warfare* provides a different model of trench warfare conducted by the British during the First World War and, thereby, highlights the significance of trench warfare munitions and the role they played in changing infantry warfare. In so doing, this book also gives a different view of the Ministry of Munitions from that usually offered and argues that certain aspects of its role in providing the BEF with munitions has been overstated by virtue of its having underplayed the work of the War Office, while overlooking that conducted by the Royal Engineers in France.

Chapter 1

Invention, Innovation and Trench Warfare

There is no question that warfare went through massive changes during the Great War. The role of invention in the transformation of warfare on the Western Front is often underplayed in respect of those inventions and innovations which brought about fundamental change to infantry warfare. This is partly because the real war-changers have not always been identified, then or now. The significance of invention as a process and as a product of that process is not always recognized in contexts other than those which are technological and technical. Thus, the true significance of some inventions has tended to be missed.

'Invention' defines the technical characteristics of a device which relate to how it functions and this, in turn, has a direct bearing on tactics, a relationship that is not well explored in relation to munitions. While this is true of all weapon systems, it is especially so in the case of trench warfare munitions devised during the First World War. The transformation of any novel device from prototype to standardized equipment has its origins in the technical characteristics of that device via a process of development. Thus, the technical characteristics specific to particular grenades, mortars and their ammunition are central to the analysis of the technical–tactical relationship. An understanding of invention and technical design – the mechanical arrangement of the component parts – is essential to an appreciation of the relationship between specific munitions and the evolution of tactics.

The technicalities of any device define its utility, functionality and reliability. These three characteristics are at the heart of the usefulness of a munition. Utility concerns its fitness for the purpose for which it is intended and the success rate of the device in an operational environment. It also relates to the unit cost of manufacture, unit cost to operate, unit cost to train its operators to use, and so on. Functionality concerns the mechanical arrangement of the components of the device and how these cooperate to ensure effective operation. Reliability is a measure of the state of readiness of the device to work as intended, the amount of time required to maintain it in a functionable condition, and the probability of it working successfully when used in an operational environment. All these matters are interrelated, of course. Throughout the war, these aspects had to be addressed by those responsible for devising and manufacturing novel trench warfare munitions, as well as by those responsible for evaluating them. The question of criteria and how these changed as the war progressed and expertise increased, was also a factor in the evolution of these munitions and their operational usage.

While these issues are discussed elsewhere in military terms, they are principally technical in nature and need to be considered accordingly.[1] It becomes more apparent that this is the case when the utility, functionality and reliability of several similar devices have to be considered comparatively. Some characteristics, however, are not measurable in an historical context. Whereas, technical evaluations of new devices occurred contemporaneously during the war,[2] singly and comparatively, studies of the results of such evaluations are not always possible in an historical context because much of the data is no longer extant.

There is an unspoken assumption that the best devices emerge from an evaluation process because the least effective devices are discarded.[3] This is a false assumption. It overlooks the issue of expediency and the role of failure. Failure is an essential part of any process of invention and development. This is especially applicable to the novel munitions under discussion here. Short-term failure in the context of the pressing need for quick solutions – that is to say, expediency – played a significant part in the selection of which novel munitions were not supplied for front-line use. Nevertheless, short-term failure is not a definitive characteristic of a device. Equally, the converse is true: initial success is not indicative of long-term utility. Thus, the widespread use of certain novel munitions by 1917 should not be viewed retrospectively as having been inevitable nor as having been attributable to their innate superiority over other similar devices.[4]

In the present context, the terms 'novel' and 'novelty' have meanings distinct from 'new' and 'newness'. Indeed, an appreciation of the terms helps to highlight the significance of invention. 'New' may be applied to anything that has recently come into existence, whether it be of a known pattern or of a hitherto unknown configuration, whereas 'novel' defines that hitherto unknown configuration. Thus, a novel munition is a device of a hitherto unknown configuration. This may be extended to include hitherto unknown munitions. Such a distinction helps to clarify the term 'invention'. An invention is novel, not merely something that is new.[5] Thus, an invention is a device which does not form part of the state of the art. This is best defined by reference to the Patents Act 1977.

While this book is not solely concerned with patentable inventions, nevertheless, the provisions of the Patents Act 1977, the Act currently in force in Britain,[6] provide a useful description of what constitutes an invention.[7] The provisions of this and earlier Patents Acts are especially pertinent to this study because it relies upon British patents granted during the First World War as a primary source.[8] According to the 1977 Act, to be patentable, a device or process not only has to be novel but has to have involved an inventive step in its creation.[9] The latter is concerned with what is termed 'obviousness'; in other words, whether it would be obvious to a notional expert in that field to take the step which has led to the device or process in question.[10] If it was obvious, that step was not inventive and, under current law, the 'invention' is not patentable. The Act in force at the time of the First World War, the Patents and Designs Act 1907, did not require an invention to pass the obviousness test in order to be patentable; it only had to be new, as opposed to novel, in the United Kingdom.[11] Nevertheless, the question of whether an invention was obvious at that time is of particular interest in the present context because obviousness, or its absence, sheds light on the process of invention and, as such, is relevant to the munitions of trench warfare.

The difficulty with obviousness is determining exactly what it means in a practical context since 'being obvious' can only ever be a matter of informed opinion, never fact. Did the inventor arrive at his invention by taking the next logical step forward from the state of the art or did he take a leap?[12] This has to be evaluated from the perspective of a contemporaneous notional expert at some moment prior to the creation of the invention in question. There is the added complication that in some instances an invention is, in fact, a reinvention.[13] Any reinvention of a device more than fifty years old was patentable at the time of the First World War.[14] A reinvention could take many forms. It might, for example, be a copy, made knowingly or unwittingly, of an earlier device with more modern materials or fabrication techniques. The cup discharger, a device attached to the muzzle of a service rifle to launch a grenade and supposedly 'invented' in 1916, first appeared in the seventeenth century.[15] Examples dating from 1743 are almost identical to the cup discharger reinvented during the First World War.[16] Clearly, the same idea can occur independently to different people in different times and places.[17]

Any invention created outside the geographical confines of the United Kingdom was theoretically patentable in Britain at the time of the First

World War.[18] Thus, patented inventions from that period may, in fact, have been neither novel nor new. This apparent confusion over what is a patentable invention at that time is sufficient justification for using here the term 'invention' in the sense described in the 1977 Act. Thus, in the present context, an invention is something which is novel, has involved an inventive step in its creation and is capable of industrial application; the latter criterium is included so as to exclude works of art. It may seem perverse to take the view that an invention made during the First World War should only be regarded as such if it involved an inventive step when this requirement was not part of the 1907 Act. At that time, practically no invention relating to any of the munitions under discussion here could reasonably be described as 'obvious' for the simple reason that no body of knowledge existed about grenades or mortars prior to the First World War. Obviousness can only pertain in the light of existing knowledge in a field specific to the invention in question; it cannot arise from a generalized knowledge of, say, engineering, nor retrospectively with the benefit of later knowledge. Nevertheless, some grenade inventions dating from the American Civil War and from the Russo-Japanese War could have anticipated the inventions of the Great War so the question of obviousness is not entirely redundant.

Another point needs to be emphasized in respect of the terms 'invention' and 'design': the terms 'invention' and 'design' are not interchangeable. A design is a conceptual creation and the product of that process; it is the form given to something, irrespective of whether that something is non-functioning or functionable, and irrespective of its novelty. An invention is a tangible creation of a novel means for carrying out a specific function. However, whereas a design is not an invention, an invention may involve a design element.[19]

The process of invention is as much a philosophical matter as it is one of inspiration, practicality and hard work. It invariably differs from inventor to inventor and according to circumstance. The backgrounds of inventors in this particular story were pertinent to what they devised. And while the issue of obviousness arose subsequently at some of the Royal Commission hearings after the war, it became clear that an invention was, indeed, sometimes merely a single step forward from the prior art, that is, the current knowledge in that field. Such 'obvious' single steps were often developments of new munitions to solve problems with their manufacture or practical use in the field. A leap of inspiration, on the other hand, was sometimes so fantastical that it required a change of perception by all concerned, including evaluators, to see that it was not some crackpot thing but a significant technical advance.[20]

That any invention stood out as novel, was an improvement over what already existed or satisfied a need was not always clear to evaluators.[21] As a consequence, the significance of an invention can be missed, both at the time and subsequently, especially when viewed with hindsight which tends to render obvious all inventions. At the time an invention is created, there may be no awareness of any need for it so that the invention seems superfluous or pointless.[22] Indeed, a need may have to be found to justify its existence. This was certainly the case with the rifle grenade. And to make matters more complicated, the invention sometimes consisted of no more than changing the shape of a component in a particular way so that it did something different from a similar component in a prior-art device.[23] Design, or form, is sometimes an essential aspect of invention which can make the difference between the thing working and not working, especially when it is mechanical in nature, although design alone is not sufficient to be inventive.[24] Furthermore, inventions which look different may be, in fact, essentially the same. Thus, the grenades and mortars of the First World War, which appear to be much like what had preceded them when considered from a non-technical historical standpoint, have tended to be viewed as insignificant as munitions and their inventiveness is often missed.

One approach to resolving this conundrum is to compare the function of the component parts of inventions rather than look at the form they take in any given embodiment. A patent specification describes an invention according to this principal. The comparative analysis of the technical aspects of devices from a functional perspective can be applied to individual components and to the devices in their entirety. This is a useful analytical tool which allows the importance of weapon systems to be evaluated in a systematic way according to criteria based on aspects of functionality. Correlating the results of such analyses with operational and tactical considerations can provide a clearer view of the effect novel munitions had on the conduct of trench warfare in the First World War. Without a clear understanding of an invention from a technical perspective and its relationship to the prior art, however, it is difficult to form an informed opinion about its usefulness. Without such an approach, some inventions can acquire an importance they do not warrant merely because they look as though they are significant. Moreover, contemporary political backing, or lack of it, can alter how such inventions are viewed.[25]

In an article in *The Royal Engineers Journal* of December 1924,[26] Capt Martel, one of the tank pioneers, argued that an invention goes through four stages: pure research, applied research, design and production.[27] By the term ‘design’ he meant creation of the invention. The idea was that by the time an invention passed to the production stage, all the potential problems had been resolved. This implies that the processes of invention and development occur in discrete and sequential stages.[28] In reality, they do not. Moreover, the pure research stage is largely absent as far as inventing is concerned. None of the novel munitions under discussion here emerged from pure research. Indeed, pure research is aimed at discovery – finding out how the universe works – not creation, whereas applied research is stimulated by the need to resolve a specific practical problem. It is applied research which has the potential for invention. The processes described by Martel are not necessarily sequential; the invention stage overlaps the development stages, linked by a feedback loop. Invention often arises from developmental work. This was certainly true of the novel munitions under discussion here.

Before any invention can be manufactured as a useable device, the prototype has to be taken through a production engineering stage whereby the considerations of manufacture are the principal concerns. Engineers know that, often, a given mechanism is too complex to manufacture quickly or easily, especially on a large scale and to a consistent standard. Thus, the unnecessary complexities have to be identified and designed out. This is one area where the processes of invention and development overlap. To solve a production difficulty, an innovative solution may have to be found. In peacetime, production engineering occurs before a device enters service but, during the First World War, this was rarely possible as far as grenades and mortars were concerned.

Taking an idea and turning it into a mass-producible device can be a complex and time-consuming process which can delay the introduction of the device on to the battlefield. In peacetime, this is less of a concern than in time of war. However, the urgency with which grenades and mortars were needed by the BEF meant that they were introduced before the matter of production engineering had been properly addressed. This inevitably led to operational difficulties when the devices failed to perform as predicted. A prime example of this was the No. 5 Mills grenade. Premature introduction of munitions to the battlefield is not uncommon, however; they have often been technically underdeveloped when used operationally for the first time because military or political pressure has led to their hasty introduction.[29] The naïve assumption that new weapons are fully developed when first used on the battlefield is based on a false premise and is not supported by the evidence.[30] While lack of adequate time for production engineering was one consequence of expediency, underdevelopment was also due to lack of knowledge about these munitions which only experience could remedy.

It could be argued that premature introduction of a munition is only apparent with hindsight or that it is inevitable because only usage on the battlefield can highlight shortcomings or advantageous improvements. While there is some truth in these assertions, and while it is not possible to anticipate all the problems which might arise in the field, this obscures the fact that, from a technical perspective, devices are often used operationally before they are ready.[31] Although developmental stasis is rarely reached – and then only after many years of service for a given device – nevertheless, there is an optimal point at which a technology can be said to be sufficiently well developed for it to provide most of the advantages promised when it was invented. This certainly occurred during the First World War with the tank.[32] As far as grenades and mortars are concerned, there is no question that they were mostly introduced to the battlefield before they were fully developed.[33] Inevitably, this had consequences for the sort of novel munitions which eventually became standardized within the British Army by the end of the First World War.

The situation was exacerbated by the necessity of development and operational use occurring concurrently rather than sequentially but that was not the sole reason.[34] There is a tendency to attribute blame when imperfect munitions first appear on the battlefield because it is presumed that someone must have been at fault for the failure to provide something better. This is partly because the processes of invention and development are not examined by researchers, thereby allowing the assumption that perfected munitions are routinely introduced to the battlefield to remain unchallenged.[35]

In this context, introduction means first appearance, which may be taken as covering a period of time rather than being a specific date. The duration of such a period is, of course, open to argument. It may be a matter of days, weeks, months or even years. Indeed, it might even be decades. It can be argued, for example, that the manually operated bolt-action rifle had an introductory period of about sixty years, that the tank had an introductory period of several months, while cylinder-released poison gas was introduced to the battlefield in a single day.

Geography certainly plays a part in this since a weapon may be introduced in one part of the world yet be unknown somewhere else at that time. The hand grenade is a good example. It appeared in Europe 600 years after its invention in China.[36] It can be argued that poison gas was first used on the Eastern Front in January 1915.[37] However, lethal gas was first released from cylinders against the French at Ypres in April 1915.[38] To a large extent, the definition is dependent on the criteria being applied as well as on the nature of the technology concerned. As far as the devices of trench warfare are concerned, introduction can to be taken to mean a period that varied between a few weeks and about a year. This is complicated by the fact that, during 1915, the operational life of the stopgap patterns of hand grenade was usually brief, lasting no more than months, so that the introductory period coincided with service lifespan.[39] On the other hand, the Mills No. 5 hand grenade was introduced over a period of almost year from about April 1915 to about March 1916 but was declared obsolete at the end of 1916.[40] The year-long introductory period was almost entirely due to manufacturing problems in Britain.

No perfected weapon, irrespective of how simple or complex it might be, has ever been introduced to a battlefield. It is the imperfection of weapons which encourages their improvement and development. Many of the shortcomings of new munitions do not become apparent until they have been used operationally for some period of time, partly because soldiers do things which designers and inventors have not anticipated and it takes time for a body of experience and knowledge to accumulate; in other words know-how. Development is a continuous process and stasis does not occur. Slowness of change should not be mistaken for lack of change any more than rapid change should be mistaken for technological failure in superseded devices.

Premature introduction of some grenades and mortars in the early years of the war was partly due to political interference which arose from the desire to see immediate benefits accruing from the adoption of devices which were perceived to be vitally important to the prosecution of trench warfare. There was also an unwillingness in military and procurement circles to accept that the developmental process took a length of time which could not be prescribed. Before the war, the War Office had a tendency to place demands for the supply of munitions from the established armaments firm, taking no account of feasibility. Not only was such a process inadequate for the supply of conventional munitions during the war – as highlighted by the shell scandal – but it was wholly unsuitable to the provision of munitions which had yet to be invented as was the case with grenades and mortars.

Political interest played a role in the provision of novel trench warfare munitions from the outset. Moreover, it has influenced how this provision was subsequently presented to posterity. The invention, manufacture and supply of trench warfare munitions during the first year of the war was almost entirely under the auspices of the War Office. However, that work has been overshadowed by what was subsequently carried out under the control of the Ministry of Munitions which came into being in June 1915 following the shell scandal. The view that the War Office had failed in all respects to supply the munitions needed by the BEF during the first year of the war was deliberately inculcated by the new Ministry and, especially, by Lloyd George, the first Minister of Munitions. This is epitomized in the account of the War Office activities described in the *History of the Ministry of Munitions*: it underplays the work carried out by the War Office prior to the creation of the new Ministry.[41]

Unfortunately, much of the work on grenades and mortars carried out between the autumn of 1914 and the summer of 1915 is not well documented. Neither the work conducted by the FW3 section of the Directorate of Fortifications and Works, which developed hand grenades and introduced trench catapults during the first six months of trench warfare,[42] nor the work conducted by the Royal Arsenal to develop trench mortars, is recorded in War Office files, although evaluations of some novel munitions are recorded in Ordnance Board minutes.[43] There are no records of the experimental work and manufacture of novel munitions by the Royal Engineers in France throughout the war and no description of their work in this regard was included in the *History of the Ministry of Munitions*. The bias is all the greater because, on the creation of the Ministry of Munitions, War Office staff who were working on trench warfare munitions were transferred to the new Ministry along with their files which were then re-jacketed and given new registry codes.[44] Thus, there is a temptation to view everything relating to trench warfare munitions as the work of the Ministry of Munitions because of the absence of Royal Engineer documents and a dearth of material jacketed as War Office files.[45] Thus, some archival material and some published sources have to be viewed with a certain amount of caution as they are not unbiased.[46]

When the British went to war in 1914, there was no War Office department with responsibility for the evaluation of inventions. Although an ad hoc committee had existed to consider submissions, mostly from servicemen, its function had been to assess their usefulness with a view to awarding the 'inventor' a financial consideration.[47] There was a laissez faire attitude to the matter of invention, largely because neither the War Office nor the Admiralty had to concern itself with such arcane matters. For the most part, invention was not the business of government departments.[48] The consequence of the sudden demand in the autumn of 1914 for trench warfare munitions was a sudden awareness by the War Office that it lacked a department capable of handling any aspect of their provision.

The enormity of the technical challenge to provide trench warfare munitions has been obscured by the emphasis placed on inventions which were presented as war-winners, both at the time and subsequently.[49] The concept of war-winning devices is deep-rooted.[50] In particular, the advocates of the tank, such as Fuller, Liddell Hart and Martel, presented their favoured device as a technical saviour indispensable for avoiding the horrors of trench warfare in a future war.[51] The technical failures of the tank during the First World War have been well discussed elsewhere.[52] Discussions about the validity of the advocacy of the tank pioneers have hindered a proper analysis of the role of invention in the land war, especially when many of the other, often more important, inventions were not regarded as war-winners nor had a political status. Politics has helped to obscure the importance of the devices under discussion here because they have always been regarded as insignificant to the prosecution of the war. Moreover, contemporary political interest could override technical or military considerations, irrespective of the consequences. Thus, an element of chance entered the process of providing trench warfare munitions.

The First World War forced the British government to reconsider the importance of scientists and engineers in relation to the country's ability to wage a war that became increasingly dependent on the country's industrial, technological and scientific resources.[53] The direct application of science and engineering to the needs of war was something which the British had hitherto eschewed. Moreover, for half a century, it was the British view that science and engineering were not the business of soldiers.[54] The First World War changed this and brought about a rise in technical proficiency among British infantry.[55] This was due in no small part to the demands made upon them by the technicalities of the new munitions with which they now fought.

Chapter 2

Trench Warfare Munitions Before 1914

The hand grenade and the mortar are ancient weapons, as ancient as gunpowder itself. Like most munitions, neither saw much improvement to their design over several centuries of sporadic use and, by the nineteenth century, they had become largely obsolescent. The grenade, in particular, became a device of improvisation resorted to under desperate circumstances. It is not surprising, then, that at the time of the First World War there was little enthusiasm for either device in the British Army. This lack of interest was reinforced by the belief that such munitions were only suitable at best for static warfare, for which the Army was not otherwise equipped or trained. Indeed, they had no place on a battlefield dominated by modern weapons such as the magazine-fed rifle, the machine-gun and quick-firing artillery.

During the nineteenth century, weapons technology went through a revolution which resulted in an exponential increase in firepower that outpaced tactical developments.[1] One effect of these technological changes was the rise in importance of the tactic of digging in by the infantry of Western-style armies, a practice that was made ever more commonplace from the 1850s onwards following the adoption of the Minié bullet and rifled musket. The widespread use of the rifle firing a well-obturated conical bullet meant that the depth of the lethal zone increased beyond that which an infantryman could cross to engage with a bayonet the enemy who was shooting at him before several more rounds were fired which increased the density of the lethal zone. No longer was it feasible for infantry to attack in massed formations or to remain in the open on the battlefield, although such attacks still occurred during the opening battles of the First World War.

Greater sophistication in weapons technology during the nineteenth century led to increased firepower. At about the time of Waterloo, a musket had a killing range of about 180 metres but was only accurate to about 90 metres.[2] Hence, the need for massed musket fire which compensated for inaccuracy. The accurate killing range increased to about 460 metres by the time of the American Civil War and by 1900 it was in excess of 915 metres.[3] However, during the Russo-Japanese War, it was noted that 'few Japanese dead were ever observed at distances much beyond 700 yards [640 metres] from the Russian positions'.[4]

Over the same period, artillery ranges increased from about 915 metres (9 pdr round shot)[5] to 2,740 metres during the American Civil War[6] and to 5,940 metres by 1900.[7] Round shot was replaced by explosive shell which changed the nature of the lethal zone: round shot could bounce several times through massed ranks, hitting individuals whereas explosive shells produced fragments which had a greater lethal radius at the initial point of impact. Trenches became a common feature of battles of the last two years of the American Civil War partly because of the increased lethal zone which led to an unwillingness by infantrymen to chance open battle, particularly during the Wilderness Campaign.[8] The infantry of most wars of the second half of the nineteenth century made increasing use of trenches and earthwork fortifications because of technological advances in weaponry which enabled both small arms and artillery to shoot accurately at ever-increasing ranges.[9]

By the 1870s, the pace of change in weapons technology was accelerating. New weapons began to appear in quick succession so that obsolescence became a feature of these new munitions; what was innovative in 1860 was outdated by 1880 by newer developments which were themselves superseded by those of the 1890s and the 1900s. Until the early 1800s, obsolescence had been a process measured in centuries. The invention of such munitions as ogival shells (1850s), centrefire metallic fixed small arms ammunition (1866), recoil and recuperator systems for artillery (1872), smokeless propellants (1884), high explosives (1885), quick-locking breech mechanisms for both artillery (1880s) and rifles (1839) all fuelled this revolution. The significance of such changes to how battles were fought did not become fully apparent until the Russo-Japanese War, however, although the signs were evident as early as the American Civil War.

These technological developments were aided by innovations in manufacturing techniques which allowed the cheap and reliable rifling of gun barrels and the reliable mass production of weapon components.[10] Thus, any given component of a weapon could be manufactured to a consistent standard thereby allowing it and other parts to be interchangeable with those from other weapons of the same model rather than each part being specific to a given weapon which had been the case hitherto. This transformed weapon making from an artisan business into an industry.

There were more developments in weapons technology during the second half of the nineteenth century than in the previous 200 years. And there was another factor at work which aided these changes: the rising importance of intellectual property, patents in particular, as a business asset.[11]

McNeill has suggested that the Crimean War inspired British engineers to invent munitions.[12] He cites the increase in patent applications at the British Patent Office as evidence of this.[13] While there is no question that the British public learned what was happening in the Crimea very much faster than in previous wars thanks to *The Times* and its correspondent, William Russell, and not a little help from the steamship, inventors did not respond to the war because of greater awareness of what was happening.[14] It is true that there was an increase in the number of patents granted for firearms, ammunition and ordnance in Britain during the 1850s[15] but this had little to do with the war in the Crimea. On the contrary, it was largely because of a change in patent law brought about by the Patents Law Amendments Act 1852, Britain's first modern patents act.[16]

One of the purposes of the Act was to simplify and rationalize the patenting procedure which, hitherto, had been expensive and hugely complex. After its introduction, there was a five-fold increase in the number of patents granted for inventions. The number of applications increased from 400 to 2,000 a year.[17] By 1863, the number of applications had increased to 3,000 a year but many were for old ideas. The lack of examination or search procedures during the application process meant there was no way to check whether the invention was, indeed, new, let alone novel.[18] Such shortcomings were not rectified until the Patents Act 1883, which introduced examination, and the 1902 Act, which required patent examiners to search British patents going back fifty years with regard to novelty.[19]

Thus, it is misleading to suggest that the increase in patents granted for munitions during the 1850s was because of inventors responding to the impetus of the Crimean War.[20] Indeed, there was not one patent for a hand grenade in the 1850s and only one inventor submitted a novel hand grenade to the Ordnance Board during the Crimean War.[21] There is nothing to suggest that he was inspired by the war although hand grenades were used by British, French and Russians troops during the siege of Sevastopol 1854–5.[22]

The hand grenade is supposed to have been invented by the Chinese in about the tenth century.[23] It did not appear in Europe until the fifteenth.[24] Hand grenades have always been associated with siege warfare and were often used by storming parties as well by defenders. Their effectiveness depended almost entirely upon fragmentation of the body, a cast-iron casing producing more lethal fragments than a pottery one. By the eighteenth century, elite regiments of grenadiers had come into being in European armies. The grenadier was always vulnerable to enemy musket fire while lighting and throwing his grenades. Moreover, the grenades were notoriously unreliable. The heyday of the grenadier was the first half of the eighteenth century.[25] Thereafter, interest in hand grenades waned and continued to decline throughout the nineteenth century, partly because warfare changed and battle became more common than siege. British troops used them at Sevastopol in 1954–5, again in the Sudan 1884–5[26] and improvised them fifteen years later during one of the sieges of the Boer War.[27]

Throughout all this time, the hand grenade remained essentially unchanged. It comprised a spherical container of gunpowder into which was inserted a fuze which had to be lit with a naked flame. Although pottery and even glass vessels[28] were sometimes used, typically during the sixteenth century, cast iron was more common as a casing material. Whereas a sixteenth-century fuze was typically a slow match similar to those used with matchlock muskets, an eighteenth-century fuze usually comprised a tapering wooden tube with a narrow bore filled with slow-burning gunpowder.[29] The main problems with these fuzes were their unpredictable rate of burning and their susceptibility to moisture damage. Rain rendered them useless.

Lighting and throwing hand grenades always required some trepidation on the part of the grenadier. He could never be certain what was going to happen: the grenade might explode in his face, the fuze fizzle out as he threw it, or burn for so long that the enemy was able to pick up the grenade and throw it back before it exploded.[30] These drawbacks were mostly overcome by the invention of safety fuze by William Bickford in 1831.[31] Bickford devised the fuze which subsequently bore his name to overcome the hazards of using unpredictable fuzes in commercial mining. Bickford safety fuze was soon taken up for military purposes, however, because of its reliability. Safety fuze consisted of a jute rope with a core of gunpowder, sealed with a varnish. It burned at a constant rate and was very much more moisture-proof than earlier types of fuze which made it ideal for hand grenades. The British only declared the cast iron and safety fuze type of hand grenade obsolete in 1902.[32]

The unpredictability and unreliability of the time fuze was always a serious drawback to the handling and operational use of grenades. These shortcomings exercised the minds of few inventors, however, as grenades were unimportant to most military operations. Nevertheless, a chimera which some pursued was the so-called percussion-fuzed hand grenade.[33] A percussion-fuzed device is supposed to have been invented as early as the end of the sixteenth century.[34] No one made a serious attempt to devise a percussion fuze for artillery shells until the middle of the nineteenth century and the advent of the ogival shell.[35] The notion of a percussion-fuzed hand grenade re-emerged at about the same time but there was little interest in such things as there was no incentive to produce a workable device. Captain Norton of the 34th Regiment submitted a 'detonating hand grenade' to the Ordnance Board in 1828, while William Parlour of the East India Military Seminary submitted a similar device six years later.[36] Both were rejected as 'ingenious, but not applicable to His Majesty's Service'.[37] In 1852, the Ordnance Board examined and rejected 'models and drawings' of percussion-fuzed hand grenades and shells which had been submitted by William Spencer.[38]

The Board's indifference to these devices implies that percussion-fuzed hand grenades were faulty in both concept and realization. However, an examination of Parlour's drawings shows it to have had the potential to be a viable device, although it appears to have had several drawbacks.[39] The Ordnance Board clearly regarded the gunpowder-filled, time-fuzed grenade to be adequate for the purpose and saw no need for anything more sophisticated; there was no requirement for a 'better' hand grenade.

The Americans took a quite different view of hand grenades. At least six patterns were used during the American Civil War, three of which were novel.[40] There were at least two other patented hand grenades but it is unclear whether they were ever used operationally.[41] A percussion-fuzed grenade was invented by a New York manufacturer of farm equipment, William Ketchum,[42] which he patented in 1861 when the Civil War was barely a few months old. Hence, the war is unlikely to have been his inspiration.[43] The Ketchum grenade was used by the Union Army and Navy;[44] some 90,000 Ketchums are supposed to have been ordered by the US government during the war.[45]

The Ketchum device had an ovoid body and a wooden tail with cardboard fins, so that it resembled a dart. Indeed, it had to be thrown like one to ensure that the device functioned as intended. Its fuze and detonator assembly included a percussion cap at the end of a tube which contained a spring-retained striker, the external part of which was surmounted with a disc.[46] When the latter hit a hard surface, it forced the striker against the spring into the cap, detonating the grenade. The reliability of the device clearly depended upon the strength of the spring and the fit of

Fig. 1 *Parlour's hand grenade of* c.*1834. The mushroom head slides on the grenade's neck to enable the striker to hit the cap and detonate the grenade. Note the safety pin. Many subsequent percussion-fuzed grenades used a similar operating method, including the Ketchum of 1861, the Japanese percussion-fuzed grenade of 1905 and the British No. 1 of 1908* (author's photograph of grenade in Norman Bonney's collection)

the striker inside the tube. It is not clear whether Ketchum realized that, for his grenade to function at all, the detonator assembly needed to be manufactured within tight tolerances: too tight a fit and the striker would not travel in the tube; too loose a fit and the striker might not hit the cap squarely so that it failed to detonate. The Confederate Army copied the Ketchum, renaming it the Raines, after General Gabriel Raines, head of the Confederate Torpedo Bureau.[47] The Raines sometimes dispensed with the tail and used a paper streamer instead so that the grenade could be thrown overarm which increased the distance it could be thrown. The purpose of the tail and the streamer was to stabilize the flight of the grenade and ensure that it landed fuze first.

The Ketchum had some functional similarities to the British Parlour grenade: both used a plunger or striker to hit a percussion cap to ignite the explosive; both used a mushroom extension to provide a crude, all-ways functionality; and both used a tail to help the grenade land head first so that the detonator mechanism worked. Whereas the Ketchum was used operationally, the Parlour seems to have existed only as a single prototype.[48] Nevertheless, here was an instance of two inventors seeking similar solutions to the same problem, namely an all-ways functioning percussion fuze. The Ketchum was not a success and had a reputation for poor functionality. Union troops complained that it often failed to detonate.[49] And Confederate troops soon came up with a remedy to the percussion-fuzzed grenade: they stretched out sheets of fabric over trenches and earthworks to catch the grenades and prevent the fuze from striking a hard surface.

Hand grenades were used in riverine and naval operations as well as in sieges, such as Vicksburg.[50] Technical deficiencies of Civil War hand grenades aside, the difficulties experienced by Union troops trying to storm the Confederate defences at Vicksburg using hand grenades highlighted the need for a coherent tactical system for their use, one which took account of the technical deficiencies.[51] However, use of hand grenades during the Civil War was entirely ad hoc. Moreover, a tactical system was inhibited by the fact that more than one type of grenade was used in operations and each required a different handling procedure. The possibility of developing a tactical system was severely hampered by the small numbers of grenades available and their unreliability.

The deficiencies of the Ketchum highlighted a problem that dogged all subsequent percussion-fuzed grenades. For the fuze to function correctly, it needed a reliable all-ways capability which increased the complexity of the fuze. Such a capability would allow the device to detonate irrespective