PERGAMON
International Journal of Impact Engineering 25 (2001) 315–330
INTERNATIONAL JOURNAL OF IMPACT ENGINEERING
www.elsevier.com/locate/ijimpeng

Schön's view of rifled infantry arms in the mid 19th century

D.J. Williams[a,*], W. Johnson[b]

[a]Department of Manufacturing Engineering, Loughborough University, Loughborough, UK
[b]Engineering Department, University of Cambridge, Cambridge, UK

Received 19 May 2000; received in revised form 9 July 2000

Abstract

We review "A brief description of the Modern System of Small Arms as adopted in the various European armies" by J. Schön and its introduction by A. Mordecai to indicate that they summarise the technology of both firearms and their manufacturing technology in the mid 19th century, a critical point in their development. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Rifles; Schön; Ballistics; Manufacture

1. Introduction

By following work by one of the authors on that of Benjamin Robins [1–3] we have pursued the repercussions of Robins' work on his 19th century successors as they sought to apply practically his ideas to artillery pieces (see [3]) and to small arms, the latter being the focus of this paper. Earlier work on Robins has included reviews of his investigations on the flight of projectiles and particularly on the phenomenon that was to be known as the Magnus effect [1] including the effect of shot with an eccentric centre of gravity (unfortunately the latter results were omitted from [2]). We have also studied how such defects may arise in cast shot [4,19].

Two of Robins successors were Major A. Mordecai[1] (US) and Captain J. Schön (Saxony). Mordecai served from 1839 to 1860 on the US Ordnance Board and was twice sent to Europe to study arms systems and production methods during the Crimean War. His Report of the Military Commission to Europe 1855–1856 (pp. 169–232) published in 1860, see [3], contains a full translation of the second edition of "*Das Gezogene Infanterie – Gewehr*" (Rifled Infantry Arms), published in Dresden in 1855 by Captain J. Schön of the Saxon infantry. The full title is "*A brief*

* Corresponding author.
[1] See also the work of Falk included in the further reading list.

PII: S0734-743X(00)00045-2

RIFLED INFANTRY ARMS.

A BRIEF DESCRIPTION

OF THE

MODERN SYSTEM OF SMALL ARMS,

AS ADOPTED IN

THE VARIOUS EUROPEAN ARMIES.

BY J. SCHÖN,

CAPTAIN IN THE ROYAL SAXON INFANTRY, HOUSEHOLD BRIGADE; KNIGHT OF THE IMPERIAL BRAZILIAN ORDER OF THE ROSE.

SECOND EDITION, REVISED AND AUGMENTED.
WITH EXPLANATORY PLATES.

DRESDEN:
1855.

TRANSLATED FROM THE GERMAN
BY J. GORGAS,
CAPTAIN OF ORDNANCE, UNITED STATES ARMY.

23 M

Fig. 1. Title page of the translation.

description of the Modern System of Small Arms as adopted in the various European armies." Fig. 1 shows the title page of the translation. This report professionally summarises the then current state of European small arms technologies at a key stage of their development. The translation from German is by J. Gorgas, Captain of Ordinance, United States Army. The State of Saxony was one of many similar provinces at this time; in 1849–1850 it supported Prussia but joined Austria in 1850. Schön's report is introduced at the end of the main text of the Commission by Major Mordecai.

2. Mordecai and Schön seek to build on Robins

The focus of both Mordecai's summary, PART XII of the report of the commission, and the Schön text is the potential for the widespread introduction of rifled arms to the military arm of the state. As Mordecai observes, "A review of the various systems adopted or tried of later years ... shows that the suggestions made more than a century ago, by Mr. Robbins (sic) in his 'Tracts on Gunnery' with respect to perfecting the construction of rifled barrelled pieces and of 'introducing them into armies for general use' have at last received their practical application".

Part XII of the report of the commission has two elements. The first describes the systems of small arms in use in the countries visited — particularly Russia, Prussia, Austria, France and Great Britain — noting that France, Austria, Great Britain and Russia were at war at the time. The second element is focussed on "General remarks on rifled small arms." Before reviewing the second element at length we make some remarks about the commission's comments on the small arms of the countries visited, particularly France and Great Britain.

With respect to France, Mordecai observes "The small arms used in the French Army having generally been taken as patterns for those of our own troops, are so well known as to render unnecessary a particular description of them except with regard to recent alterations and experiments." The particular experiments described are those "in progress on a large scale at Vincennes, at the school of infantry practice, under the direction of Mr. Minie, instructor of the school, to ascertain the best form of ball to be used with the rifled musket and the 'carabine' without the 'tige'.". This will be amplified later in the text. Of Great Britain he states "The system of small arms for the British Army has, within a few years, undergone a great change" He particularly notes the "'*Enfield musket*' which is now in the course of general manufacture for general use in the infantry" and the "new and neat patterns adopted for the details of this musket". Of these more later.

At the end of his summary Mordecai includes the comment: "Although great progress has undoubtedly been made of late years in the improvement of military firearms, both in Europe and America, the matter may still be considered to be in a transition state." This comment taken together with the first lines of Schön's preface to his work (the sentence that follows) place the work in its context at the time, 1855. "Science has within the last 10 years, successfully applied itself to the improvement of infantry firearms, and as the result of experiments stimulated by the introduction of percussion arms, 30 years ago, three systems have been originated and, with more or less modification, brought into use."

The wide application of the rifle required the practical resolution of the problem of "quick and easy loading with the close fitting of the ball which is requisite to give it the rifle motion imparted by the spiral grooves in the barrel". Mordecai summaries the four major methods to achieve this

TABLE OF RIFLED SMALL ARMS USED IN

DESIGNATION OF ARM.		Caliber.	Length of barrel.	GROOVES.				Twist.	TIGE.		WEIGHT.	
				Number.	Width.	DEPTH.			Diameter.	Length.	Without bayonet.	With bayonet.
						Breech.	Muzzle.					
		Inches.	Inches.		Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Pounds.	Pounds.
RUSSIA	Brunswick rifle	0.69	31.5	2	0.31	0.032	0.032	31.5	......	......	9.7	11.35
PRUSSIA	Needle gun	0.62	36	4	0.23	0.03	0.03	29	......	......	10.75	......
	Rifle à tige	0.577	27.6	8	0.11	0.025	0.025	36.8	0.27	1.7	10	......
	Wall piece	0.708	41	4	0.27	0.017	0.017	60	0.3	1.85	9.53	10.33
AUSTRIA	Rifle-musket, (1854)	0.55	37.5	4	0.21	0.025	0.02	75	......	......	9.5	10.25
	Do. (Jager)	0.55	28	4	0.21	0.025	0.02	75	......	......	9	10.5
	Do. with tige	0.55	28	4	0.21	0.025	0.02	75	0.25	1.5	9	10.5
FRANCE	Rifled musket à tige	0.708	42.64	4	0.27	0.02	0.004	78.75	0.35	1.5	9.34	10
	Carabine à tige, (1846)	0.708	34.2	4	0.27	0.02	0.012	78.75	0.35	1.5	9	10.7
	Do. des Cent Gardes	0.36	31.5	5	......	......	......	31.5	......	......	7	......
GREAT BRITAIN	Minié musket, (1851)	0.702	39	4	0.25	0.02	0.01	78	......	......	9	10.5
	Enfield rifle-musket, (1853)	0.577	39	3	0.262	0.014	0.004	78	......	......	8.7	9.2
	Do. do. (1855)	0.577	34	3	0.262	0.014	0.004	78	......	......	......	......
	Do. artillery carbine	0.577	24	3	0.262	0.014	0.004	78	......	......	6.5	8.25
SARDINIA	Rifle	0.665	29.5	8	0.092	0.012	0.012	52.7	......	......	9.25	11.66
SAXONY	Rifle, (musket à tige)	0.577	40.4	4	0.20	0.025	0.025	64.5	0.3	1.7	......	......
SWITZERLAND	Rifle	0.414	32	8	0.08	0.015	0.015	36	......	......	9	9.51
NORWAY	Breech-loading rifle	0.65	36.5	......	......	......	......	58	......	......	......	......
UNITED STATES	Rifle-musket, (1856)	0.58	40	3	......	0.015	0.005	72	......	......	9.18	9.9
	Rifle, (altered)	0.58	33	3	......	0.015	0.005	72	......	......	9.68	11.68
	Pistol-carbine	0.58	12	3	......	0.008	0.005	48	......	......	5*	......
	Rifled musket, (altered)	0.69	42	3	......	0.015	0.005	72	......	......	9.34	10.10

* Detached stock included.

Fig. 2. Mordecai's summary table showing the similarities of the technologies applied.

that were in place at the time. These were, first, the use of a patched ball which had been current for many years; second, breech loading which was just beginning to emerge as a practical solution and third, the ramming or *tige* system. In the *tige* system the projectile is upset within the barrel using the ramrod on an anvil or *tige* in the powder chamber — this is now usually known as the pillar breech. The fourth system is the expanding cylindro-conical ball suggested by Delvinge in 1840.

THE ARMIES OF DIFFERENT COUNTRIES.

BALL.				CHARGE OF POWDER.		Highest sight mark.	REMARKS.
Kind.	Diameter.	Length.	Weight.	Kind.	Weight.		
	Inches.	Inches.	Grains.		Grains.	Yards	
Ogival, with two guides................	0.685	1.18	787	....	....	......	English two-grooved rifle, with sword-bayonet.
Sphero-conical..........	0.63	1	440	Musket grain.......	56	......	Priming attached to cartridge.
Cylindro-conical, with two grooves......	0.56	1.03	366	Do.	56	580	Patent breech, with conical chamber.
Cylindro-conical, with three grooves.....	0.68	1.24	483	Do.	100	500	Do. do.
Cylindro-ogival, with two deep grooves..	5.45	1	450	Large musket grain..	62	800	Wilkinson's ball.
Do. do.	5.45	1	450	Do.	62	800	Do.
Do. do.	5.45	1	450	Do.	62	1,000	Do.
Solid, cylindro-ogival, with three grooves.	0.695	1.12	720	Musket............	70	875	
Do. do.	0.695	1.12	720	Do.	70	1,300	Sword-bayonet.
Cylindro-ogival, solid.................. .	....	....	180	Do.	30	......	Sword-bayonet; breech loading; priming attached to the cartridge.
Conoidal, with expanding cup............	0.69	1.03	680	Do.	68	1,000	
Conoidal, with expanding plug......	0.568	0.96	525	Do.	68	800	
Do. do.	0.568	0.96	525	Do.	68	800	
Do. do.	0.568	0.96	525	Do.	55	300	Sword-bayonet.
Cylindro conical, without grooves........	0.64	0.93	540	Rifle...............	53	......	Sword-bayonet; cylindrical chamber 0.44 inch in diameter, and 1.85 inch deep.
Cylindro-conical, with one deep groove..	0.57	1	418	Rifle...............	85	......	Same ball used in rifles without the tige.
Cylindro-ogival, solid, with two grooves..	0.41	0.94	240	Musket............	62	800	Cylindrical chamber, of same diameter as the bore.
Do. do.	....	....	....	....	....	......	
Cylindro-ogival, three grooves, cavity in base.	0.5775	1.025	510	Musket............	60	1,000	
Cylindro-ogival, three grooves, cavity in base.	0.5775	1.025	510	Do.	60	1,000	Sword-bayonet.
Cylindro-ogival, three grooves, cavity in base.	0.5775	1.025	450	Do.	40	400	
....	0.685	1.05	740	Do.	70	900	

Fig. 2. Continued.

The latter, in 1855 and still, is known as the *Minie* system. Mordecai also comments that the introduction of the new systems has led to the increasing similarity of the arms supplied, for example that they have very similar calibres; see Fig. 2. Schön in turn makes three classifications, as has been indicated above; these include "the system of the normal form of the ball" — "where we endeavour to preserve it in the shape in which it has been carefully designed". This classification includes the patched ball — a combination of a cloth patch and a conventional spherical ball to ensure a tight fit in the rifled barrel. He also describes "the system of the uniform disfiguration of the ball" during ramming, of which the *tige* is a variant and "the breech loading system".

Schön notes that the form of the rifling itself changed significantly during the period covered by the study as understanding increased but that it was the shape of the ball that "has however undergone the most marked change". Ball is usually used in to refer to any projectile geometry. In his report he particularly emphasises the effect of the geometry of the projectile on its flight and the mode of its rotation thus — "The rotation of the ball from a rifle, is a motion about an axis, impressed on it by the twist of the grooves; and it is pretty well certain that a rotation about the centre of gravity occurs only as an exception, due to a faulty construction of the missile or some accidental circumstance." He also notes the importance of the forward position of the centre of gravity of the ball, i.e. towards the nose of the projectile.

The objective of such rifled arms is of course to allow the achievement of longer ranges — of 500 and 600 yards — with more accuracy and less drift. This consequently required the development of simple and robust sighting systems. "The most practical method seems to be that adopted in the English school of infantry practise, viz that of exercising the soldier to observe carefully the appearance of a man at different known distances from him … ."

Mordecai notes that the adoption of these systems required changes in manufacturing practise. One of these was in the manufacture of the projectiles — "making the balls by pressure in dies (instead of casting them in moulds)" — lead cylinders were fed through progressively grooved rollers in order to crop spheres[2]. More particularly, manufacturing innovations were required to achieve the tolerances necessary for the barrels thus — "At the Arsenal of Vienna the variation allowed in the diameter of the bore is *half a point* or 0.0038 in. In the English arms it is said to be 0.001 in. At our armouries the allowance of variation was formerly 0.01 in but it has now been properly reduced to 0.0025." This difference of requirements for accuracy in the manufacturing process between the US and UK is reviewed later in the text.

3. Schön's contribution

Schön begins the core of his contribution by stating the requirements and options for design decisions; increased facility of loading; increased accuracy and range; the charge; the inclination of the grooves and the diameter and form of the ball. After a wide ranging introduction to the practical aspects of the problem, Schön turns to describe the solutions. He begins his presentation by describing "the first impulse" of Delvigne which was to apply a rim to the breech chamber, to use a ball with considerable windage" — the gap between ball and bore — "and to then use the ram rod to ram the ball against the rim of the chamber and consequently driving the lead of the ball into the rifling". This of course modified the geometry of the face of the ball and led to inaccuracies of flight. His colleague Pontchara then cupped the face of the ramrod and used a protective sabot on top of the ball. Subsequent variations of this approach are described including the oval of Lancaster (equivalent to a two grooved bore) and the belted ball.

[2] The mechanics of this and related processes are presented in Ref. [18].

The next major innovation described is the bolt-operated-breech-loading needle gun of Dreyse developed in Prussia "with great secrecy". This is described at great length, reflecting its importance. The needle gun was the first widely applied bolt action breech-loading rifle. Central to the success of the needle gun is the use of a breech-loaded paper cartridge with a fulminate primer held in the base of the bullet between the bullet and the charge. The needle passes through the charge to ignite the primer. The Norwegian breech loading rifle on which the needle gun is based is also described. Interestingly, in his summary, Mordecai observes the following. "Prussia is the only large state in which an arm of this kind has been extensively adopted for military service, and the absence of any imitators of her system in this respect seems to be a tacit acknowledgement of the general disapproval of it in other countries." History tells a different story. While discussing breech-loaders Schön briefly covers the *drehlinge* or revolvers "that reappeared 5 or 6 years ago" manufactured by Colt and the "preferable" British *Adams and Deane* improvement which added a reinforcing strap over the revolver cylinder to improve its gas tightness.

4. The Thouvenin and Minie systems

The next major innovations described in detail are those of the *tige* created by Thouvenin and the Minie system. In the *tige* system Thouvenin adopted the cylindro-conical ball as invented by Delvinge, removed the need for the sabot on top of the ball by using a conical cavity in the ramrod and used a central stem or pillar, the *tige*, within the breech chamber; see Fig. 3. On loading, the projectile is supported by the pillar above the annular powder charge, it is then upset into the rifling with a number (usually three) of blows of the ramrod — this is the most significant of Schön's "disfiguration" systems. The *tige* also prevented crushing of the powder and promoted improved ignition. Thouvenin's projectile also included a number of annular lubricating grooves — cannelures — around its cylindrical portion and therefore had a centre of gravity towards its point. However, non-uniform "disfiguration" during the ramming of projectiles would lead to differences in accuracy and range.

In the *Minie* system, see Fig. 4, which appears to have been also primarily French, developed a three annular grooved cylindro-ogival projectile is used. The key to the innovation is the use of a conical cavity at the base of the projectile this being filled with a sheet iron cup or *culot*. This

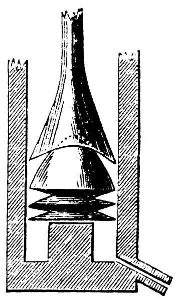

Fig. 3. A *tige* breech, reproduced from J. Schoffern, Projectile Weapons of War, Longman, Brown, Green and Longmans, 1858, printed in facsimile by Richmond 1971.

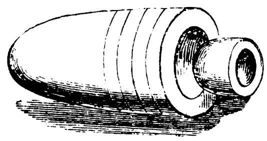

Fig. 4. A *Minie* projectile, reproduced from J. Schoffern, Projectile Weapons of War, Longman, Brown, Green and Longmans, 1858, printed in facsimile by Richmond 1971.

removes the *tige* and *sabot* used to protect the geometry of the projectile. On ignition the expanding gases drive the *culot* into the conical cavity and expand the base of the bullet into the rifling. Importantly this retains the "normal" designed geometry of the projectile. The *culot* was later found to be unnecessary but was sometimes replaced with a boxwood plug.

Schön describes in detail the *Minie*- and *tige*-based systems adopted by European armies including all of their significant dimensions — they could be replicated from the text and figures. He also describes a number of test programmes conducted by different governments to evaluate a variety of designs. These include a test at Woolwich in 1851, in Enfield in 1852, a test in Belgium conducted by Timmerhaus in 1853 and, in an Appendix to the main text, experiments in Switzerland held in 1847. Experience showed that the *tige* approach created an accurate and long-range rifle with a shallow elevation — the shallow elevation being critical for the accuracy and range of the projectile and in order to permit the easier judgement of range and aim. It was widely used by sharp-shooters — recall that this is an American translation — and by experienced troops because it was difficult to load. It could also be used as a rapidly loaded "smoothbore" with smaller diameter projectiles.

5. The Enfield trials

For the English reader, perhaps the most interesting description is that of the trials held in Enfield in 1852 which compared rifles by Purdy (sic), Lovell, Greener, Richards, Lancaster and Wilkinson with a two groove rifle, an 1851 Minie rifle (primarily created by Lovell, an American, of the Royal Armouries and the result of an earlier 1851 trial at Woolwich) and a new rifle made in the Royal Armoury at Enfield. The primary objective of the trial was to determine which rifle was effective and would allow the soldier to carry 60 rounds of ammunition without fatigue. Further objectives were to establish the influence of the number of grooves in the rifling, remove the culot or cup, modify the ball and to "make a breech sight less faulty than the one in use in the Minie rifle (of 1851)". The Enfield design performed well, it was essentially an evolution of the 1851 design with a smaller and hence lighter projectile. Three grooves were chosen, a coarse grain powder used and the projectile somewhat modified. Guns were loaded using a paper cartridge. The cartridge held powder, projectile and the paper of the cartridge itself was formed into a wad. The paper package or envelope of the cartridge assembly required considerable greasing in order to get the best performance. "The efficiency and accuracy of this rifle exceeded all others of the grooved arms up to 800 yards, especially when loaded with the greased envelope." At the close of the experiments further work was done by Pritchett to improve the projectile further. In practice also Minie arms were much less liable to fouling than Thouvenin designs.

This review of the solutions closes with short sections on the Swiss system, a variant of the patched ball; Wilkinson's system, that uses a two-part projectile consisting of a hoop that is driven by a cone to fill the rifling and the elliptical section barrel of the Lancaster system. Schön is somewhat critical of the latter with respect to its function and level of innovation over American and Danish practice.

6. Schön's summary

Schön's conclusion has two parts. In the first, by beginning with a brief redefinition of the problem, he summarises the contribution of each design. He particularly emphasises the importance of the Thouvenin system and the pointed ball indicating that it changed the tactics necessary in battle by not allowing the use of "flying" artillery. "With the appearance of Thouvenin's and the accompanying pointed ball, the rifled arm assumed a different aspect, since the range of its execution was limited only by the extent of human vision. No longer can the artillery, when opposed to infantry, take up its position and securely discharge its rounds of grape and canister, secure of immunity from any but a random shot from its adversary. At this distance it is now at the mercy of the foot-soldier ..." He contrasts this with the performance of the Minie system "this system does not essentially increase the accuracy and the range is diminished; but it attains two advantages, viz. a still greater facility of loading and the preservation of the original form of the ball". The two-part Wilkinson projectiles "surpass nearly every other in accuracy, range and penetration". Breech-loaders rate little discussion but the needle gun "is decidedly the most expeditious in loading, and equals the Thouvenin in accuracy and range".

7. Schön's ideas on the flight of projectiles

The second part of Schön's conclusion is of a different character to the rest of the text. Here he makes his own contribution "to ascertain the deviation caused by the resistance of the air on the various forms of balls" particularly on "the figure of the pointed part". Schön compares the flight of the cylinder, the sphere, the cone, and the surface forms generated by the rotations of intersecting circular arcs and the parabola. The key elements of his approach are as follows:

"The passage of the ball through the air necessarily infers that every particle of air lying in the path of the ball is thrust out of its place at a certain angle with the surface of the ball. According to the law of the impact of elastic bodies, the angle at which the particles of air leave the surface of the tapering part will be equal to the angle at which they impinge on it. These deflected particles of air will form themselves into conical fascicles '(little bundles)', the axes of which will be the element of greatest deviation, the other divergent elements of each fascicle collecting around this one.

Each impinging element of air is reflected in this way, and the more the axes of the several fascicles of elements diverge from each other and the more easily the deflected elements escape, and the less will be the resistance of the air.

Before entering further on the consideration of these deviations it may be remarked that it will conduce a clearer conception, and will not affect the result, to consider the ball at rest and the air moving in parallel lines against it."

This approach anticipates the more modern fluid mechanics approaches of stream lines, recognising the equivalence of the relative velocity with a change in reference frame by "stopping the ball". Schön uses the approach to explore the resistance of the air to each projectile geometry to indicate that the paraboloid has "the least opposition from the resistance of the air" and more importantly to explore the effects on "a ball which having been discharged, from any circumstance assumes a position different from its normal position with reference to the trajectory". Again he demonstrates that for the paraboloid "the return to the normal position is easier". This part of his discussion closes by emphasising the importance of no alteration of the shape of the ball by ramming as in the *Minie* and *Wilkinson* systems and a summary of the effects of charge weight. In contrast to the emphasis of the early part of the text he makes no comment about the position of centre of gravity of the ball.

8. Who did invent the expanding projectile?

Mordecai notes that the expanding projectile was mentioned by Greener in 1831, see the later descriptions of trials in 1835. Each country makes it's own claim for the invention of the expanding bullet, the key enabler for the breech-loading rifle. W.W. Greener in his book "The Gun and its Development" [5] gives an account of the contribution of his father, W. Greener. After describing Devigne's invention of the shouldered chamber in 1826 and subsequently the pillar breech or *tige*, W. W. Greener continues: ".. in 1835 the late W. Greener produced the perfect expanding bullet". This bullet was essentially a ball with a central hole filled with a tapered metal plug and was tried in August 1835. Returning to the younger Greeners' account "The report of the trial, although very favourable to the invention, received scant attention by the authorities, the invention being rejected on the ground that the bullet was a compound one. The matter was resuscitated when, in 1852, the Government awarded M. Minie, a Frenchman, £20,000 for a bullet of the same principle adopted into the British Service. Mr. Greener then made several unsuccessful attempts to obtain from the British Government some recognition of his claims to the inventions; but not until Mr. Scholefield, the member for Birmingham, moved in the House of Commons for correspondence between the Board of Ordinance and Mr. Greener, and the papers connected therewith, was this act of injustice truly exposed. Eventually the Government, after much trouble, admitted Mr. Greener's priority and awarded him £1000 in the Army Estimates of 1857, for 'the first public suggestion of the principle of expansion, commonly called the Minie principle, in 1836'." W. Greener did not utilise a cylindro-conical geometry — his ball was spherical.

9. The impact of the 1853 Enfield on manufacturing industry

As we have seen in the text Schön discusses at length the highly successful 1853 Enfield design that emerged from the 1852 Trial. We may note in passing that the Enfield cartridge contributed to the start of the Indian Mutiny [6]. The native soldiers were instructed to rip apart the paper cartridge of projectile, charge and wadding with their teeth and strongly objected to this as large quantities (as has been indicated earlier) of beef fat were used as a lubricant on the cartridge and projectile. The weapon was also used in the American Civil War. It has been estimated that some

428,000 were bought by the Federal Government and 90,000 by the Confederacy [7]. This firearm and its replicas are still favourites of black powder shooters today. As well as its impact as a weapon, the introduction of the Enfield had wide impacts on gun making and the locations for gun making in the UK.

As Mordecai observed "the variation allowed in the diameter of the bore.... is said to be 0.001 in". This highlights that at this period a number of significant technical changes were taking place both by the utilisation of machine tools and of measuring machines. Whitworth was for example active in both and gunnery systems at this time and patented his own spectacularly accurate, but expensive, rifle design with a hexagonal bore cross section and an elongated projectile [17]. The key transition from a manufacturing viewpoint was that the tolerances demanded from the gun maker for the 1853 pattern were much higher than before and for the first time these tolerances were checked against gauges held by the Board of Ordinance in each factory [7]; some of the weapons made had interchangeable components. A well-illustrated article is Ref. [8] which shows photographs of the gauges and their practical use.

It is of interest to the student of manufacturing to put this in context. At this time Birmingham was the centre of the UK gun making industry. For example between 1804 and 1815, 1,743,824 military weapons, 3,037,644 military barrels and 2,879,203 gunlocks were completed by the Birmingham gun makers and their Black Country suppliers together with an estimated further million guns for the East India Company and 500,000 sporting guns [9]. It will be clear that the Birmingham trade made "hay" during the Napoleonic Wars (with a significant fall off of orders after 1817) and sought to repeat this during the Crimean War (1854) when there was to "be both guns and butter" in the period of colonial expansion. As with much of manufacturing industry in the 19th century [15] the Birmingham trade was the sum of the activities of a large number of small masters rather than running on the factory system — Boulton and Watt at the Soho Manufactury was "a magnificent exception" [10].[3] These masters, while they used machinery for barrel boring did not use machine tools widely in the manufacture of locks and other parts — this being largely carried out by gun and lock filers — complete guns were therefore fitted rather than assembled. Military fire arms had been made under the "Ordnance System" since around 1720 [12]. Under this system orders to manufacture to pattern for the various components — locks, barrels, small-work and furniture — were negotiated with many suppliers, and the guns fitted together by "rough stockers and setters up". As Wilkinson notes in his book "Engines of War" published in 1841 [10] the way to make locks is "*good filing and fitting with excellent tools*", his italics. This was about to change radically. Chambers [11] observes "it was not until the last quarter of the 19th century that machinery was devised (or imported from America) which would enable standardised factory production to compete with the products of the myriad small masters who supplied the highly specialised products of the finished metal trades: light arms, jewellery, sporting guns, japanned products, etc." The 1853 Enfield brought that change into gun making and radically changed the form of an industry cluster. As Walter [9] states "the industrial revolution was really a century long transition to mechanisation that had by-passed much of the gun making industry ...

[3] It is interesting to observe that the success of the Soho Manufactury itself was based upon a militarily driven manufacturing process innovation — Williamson's cannon boring machine — this being used to bore steam engine cylinders to fits of "a thin sixpence" between piston and bore — not perhaps the most exacting of tolerances!

Though a hard won living could be made from production of sporting guns, no two of which were identical or whose parts were not required to interchange, it was quite another matter to produce many thousands of guns whose acceptance depended on interchangeability of parts. Very few of the 'manufacturers' in mid 19th century Birmingham, though their combined output was immense, had the production capacity necessary for large-scale production and even the largest made extensive use of subcontractors".

Greener [5] tells part of the story of the change for gun making in the UK — "Mr. Prosser was requested by the Government to report as to the possibility of making guns to the interchangeable plan. This was in 1850; in 1852 Colonel Colt was examined by a committee of the House of Commons with reference to the same subject, and upon the strength of his representations, a Commission visited the United States; the result of that visit was the founding of the Enfield Factory, the purchase of American machinery and the introduction of the interchangeable system of manufacture into England at the close of the Crimean War."[4]

As indicated the Royal Small Arms Factory at Enfield, England, was equipped with American made machinery particularly for wooden stock making and was by 1858 capable of manufacturing rifles to the pattern of 1853 with completely interchangeable components [12]. Fig. 5 shows Mordecai's plan of the Enfield factory — it is interesting to note the level of vertical integration. One of its chief engineers was James Henry Burton formerly of the Harpers Ferry Armory[5] [13]. We should note Mordecai's comment concerning the differences in tolerances applied in the US and the UK — the UK military armouries were targeted to achieve higher tolerances than their US armory colleagues. About a year later the London Armoury Company of Bermondsey began to make interchangeable Pattern 1853 rifles with machines [12].

Further, Mordecai reports in the text of his Commission when discussing the Enfield rifle: "This musket has a barrel thirty-nine inches long, with a bore of 0.577 in; it is rifled with three grooves, which have a twist of six and a half feet or half a turn in the length of the barrel; the grooves are 0.014 in deep at the breech, diminishing to 0.004 in (scarcely perceptible) at the muzzle. In the arms, made by contract, at Birmingham, the depth of the grooves is uniform; the contractors having no machinery adapted to cutting grooves of increasing depth."

The success of these new factories and the technology within them caused some disquiet in the Birmingham gun making industry. "By 1858 the manufactury at Enfield was turning out 2000 rifles a week. These were mainly the long Enfield rifle of the pattern decided in 1853 by a military committee (a committee having among its advisors the Birmingham gun makers Greener, Westley Richards and Wilkinson). To compete with the new arms factory the larger firms in Birmingham subscribed capital towards the building of a factory to make rifles with machine tools .... called the Birmingham Small Arms Company (BSA)" [14]. This was founded on June 7 1861 when 13 of

[4] Greener [5] speculates that "Had the workmen of Birmingham worked during the rush (of the Crimean War), instead of immediately and continuously striking, in all probability the Government factory would never have been founded; and the two large factories built afterwards in Birmingham for the manufacture of military arms by improved machinery would have been fully employed." This has echoes for the UK of current discussions on the future of *Rover Cars* and recalls the history of industrial relations in the West Midlands for the decades of the 1960s and 1970s!

[5] When Burton was the Assistant Master Armorer at Harper's Ferry he generated his own plug-less variant of the Minie bullet [13].

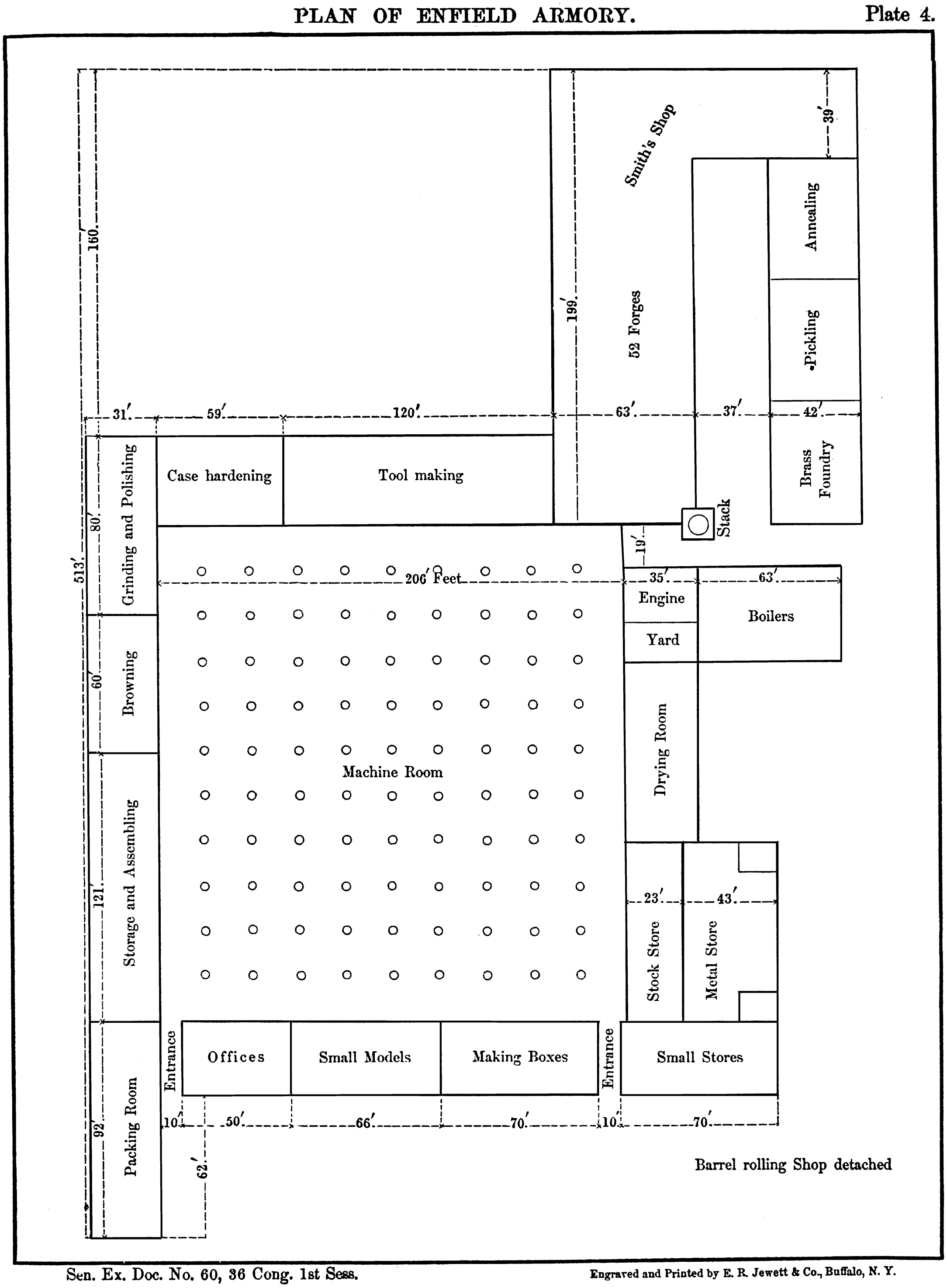

Fig. 5. Mordecai's plan of the Enfield Armory.

Birmingham's best-known gun makers gathered at the Stork Hotel to consider "forming a company to make Guns by Machinery". One of the first actions of the company was to order stock-making machinery from the Ames Manufacturing Company in the USA and metal working machinery from Greenwood and Batley of Leeds [9]. This single approach contrasts with the difficulty of handling early orders placed in Birmingham to produce the 1853 pattern which required barrels from seven contractors to be assembled with locks from seven further subcontractors with minor parts from further contractors. It is worth noting that the Ames machines are automated woodworking machines for stock-inletting (see the photograph in Ref. [16] of one of the actual Enfield factory machines). These consequently do not require the level of accuracy of metal working machines. As has been indicated earlier, Whitworth was becoming active in this sector and would have no doubt influenced the levels of precision sought in England. Greenwood of Greenwood and Batley was a Whitworth protégé.

Elsewhere, in the 1910 edition of his book Greener notes "the military branch of the (Birmingham) trade was checked by the establishment of fire-arms manufactories at Lewisham and Enfield.... and it is upon the sporting trade that the Birmingham industry still depends".

The above gives us a Victorian example of the impact of product and manufacturing technology change and of state intervention in an industrial sector and its effect on other national regions. It also allows us to appreciate a little about those industries that can survive through many economic cycles. With the introduction of the factory system using machine tools to Birmingham gun making, a mechanised industry was added to the existing hand work industry. While the volume, mechanised industry has disappeared, there is still a vigorous Birmingham trade in sporting guns — high added value products usually tailored to individuals and with considerable "hand" working. As well, some of the companies involved in the 1853 trials such as Westley Richards still survive.

10. Conclusion

Schön's engineering contribution is clear, he summarised and systematised both practise and current thinking on a complex multi-dimensional problem — barrel, charge and projectile characteristics and the realities of use of the firearm including outline ballistic tables — with a scientific approach including modern fluid mechanics communicated in a readily understandable way to his military colleagues. He closes his introduction by writing "Should I succeed in this essay in serving any of my comrades in arms, one of my most constant aspirations will be fulfilled". He succeeded and his account remains interesting and readable a century and a half later.

As Mordecai commented at the start of his Introduction, during the 1850s military firearms were seeing a period of major change facilitated by the introduction of percussion ignition in place of the flintlock that had been ubiquitous for two centuries. Most nations introduced a muzzle loading rifle based upon the Minie — expanding projectile — principle during this or the following decade. However, the US was late in adopting this technology and only approved arms for it in 1855. The 1855 pattern (shown as 1856 in Fig. 2) also included a novel form of percussion ignition — the Maynard tape primer (not unlike a child's paper roll of "caps"), perhaps a reason for the delay. No doubt Captain Gorgas's translation was part of the evidence used to justify the change. However, advanced US breech loading technologies as embodied in the Sharp's carbine and Colt's revolver were applied in the British and other European armies by the mid 1850s. Schön focuses on the importance of the French in the development of these technologies. The French were early adopters of the *tige* in their patterns of 1846, but late in their final adoption of the Minie projectile. The *tige* was removed in 1860.

Many of the Minie designs were subsequently soon converted to breech loading designs as they did not require the use of the ramrod to "disfigure" the projectile into the rifling and allowed rapid loading and many more firings before it was necessary to clean the bore. The 50 years that followed saw a period of rapid development of breech-loading designs consequent on the development of the expanding projectile, cleaner propellants than black powder and as we have observed more precise manufacturing technology. The design of firearms has, relatively, improved little since the introduction of the late 19th century rolling block and bolt action breech-loading designs except, of course, for repeating designs and the application of new materials.

References

[1] Johnson W. The magnus effect — early investigations and a question of priority. Int J Mech Sci 1986;28:819–72.
[2] Johnson W. Short unpublished manuscripts of Benjamin Robins. Int J Impact Engng 2000;24:417–28.
[3] Johnson W. Alfred Mordecai (1804–1887) an American ordnance and gunpowder researcher of the 1840s. Int J Impact Engng 2000;24:843–60.
[4] Williams DJ, Johnson W. A note on casting iron cannon balls: ideality and porosity. Int J Impact Engng 2000;24:429–33.
[5] Greener WW. The gun and its development, 9th ed. 1910. Facsimile New York: Bonanza Books, 1967.
[6] Feiling K. A history of England. London: MacMillan/Book Club, 1970.
[7] Pegler M. Powder ball small arms. Ramsbury: Crowood Press, 1998.
[8] Jacques P. Peter Jacques inspects Enfield inspectors gauges. Black Powder 1993;40:26–9.
[9] Walter J. The rise of the piled arms, a short history of the Birmingham small arms company. Guns Review 1984;24:310–2.
[10] Wilkinson H. Engines of war, 1841. Facsimile by Richmond: Richmond Publishing, 1973.
[11] Chambers JD. The Workshop of the World, British Economic History 1820–1880. Oxford: Oxford University Press, 1974.
[12] Bailey DW. British military Longarms 1715–1865. London: Arms and Armour Press, 1986.
[13] Peterson H. The treasury of the gun. New York: Golden Press, 1962.
[14] Dunham K. The gun trade of Birmingham. Birmingham: City of Birmingham Museum and Art Gallery, undated.
[15] Mathias P. The first industrial nation — an economic history of Britain 1700–1914. London: Methuen, 1969.
[16] Gilbert KR. Catalogue of exhibits with historical introduction, The Machine Tool Collection, The Science Museum. London: HMSO, 1966.
[17] Atkinson N, Whitworth J. The worlds best mechanician. Stroud: Sutton Publishing, 1996.
[18] Johnson W. The mechanics of some Industrial Pressing, Rolling and Forging Processes. In: Hopkinson HG, Sewell MJ, editors. The Rodney Hill 60th Anniversary Volume. Oxford: Pergamon Press, 1981. p. 303–5.
[19] Johnson W. A brief account of his report, Military Commission to Europe 1855–1856. Int J Impact Engng 2000;24:861–9.

Further reading

Falk SL. Divided loyalties in 1861: the decision of Major Alfred Mordecai. American Jewish Historical Society 1959, XLVIII (3): 147–69.

Falk SL. Major Alfred Mordecai: the first ordnance officer to apply scientific methods to armanent. Ordnance, 1959 (Nov.–Dec.), p 395–97.
Falk SL. Notes and documents: Jefferson Davis and Josia Gorgas, an appointment of necessity. The Journal of Southern History 1962; XX (1): 84–86.
Falk SL. How the Napolean came to America. Civil War History 1964;X (2): 149–54.
Falk SL. Artillery for the land service; the development of a system, military affairs 1964; XXVIII (3): 97–100.
Falk SL, Mordecai, Alfred, dictionary of American military biography. Spiller RJ, editor. Westport CT, Greenwood Press, 1984, p 783–86.