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Rise and Progress of
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~~Engineering~~ Industry
~~from Essex Point of~~

~~Period~~ 1909

E. A. Brayley Hodgetts

~~Sept 1904~~

~~Paul Mills~~

~~Waltham Abbey~~

(~~Figure of~~
~~from Railings~~)

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RISE AND PROGRESS OF THE BRITISH EXPLOSIVES INDUSTRY

by

E. A. BRAYLEY HODGETTS

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(INCOMPLETE PHOTOCOPY)

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THE RISE AND PROGRESS OF THE BRITISH EXPLOSIVES INDUSTRY

HISTORY OF GUNPOWDER

By E. A. Brayley Hodgetts

THE highest development of civilization has synchronized with the increase and growth of the means of destruction at the disposal of mankind. To the superficial untrained mind, and more particularly to the loose-thinking satirist of modern progress, the above statement will appear as at once a paradox and an additional argument against the highly organized and artificial structure of contemporary society. But dispassionate reflection will show that the better the means possessed by society of self-preservation, and consequently of defence and offence, the more assured must be its continuance, the less exposed to disturbance and interruption its natural growth. The evolution of society has, however, proceeded from stage to stage by conflict, for, as the late Sir W. R. Grove, the discoverer of the correlation of the physical forces, postulated, the law of antagonism is the foundation of progress. It is by his superior means of destruction that man has conquered the wild beasts of the field and forest, and it is thanks to the same means that the cultured races have succeeded in imposing their civilization on barbarians and savages. If, however, the increased power of destruction possessed by modern society makes our means of defence and offence more deadly, the actual effect of the invention or discovery of these destructive methods has been to render modern warfare increasingly humane. In the old days of hand-to-hand combat, the proportion of killed and wounded in a battle was far greater

than has been the case since the invention of gunpowder, and to-day the terrific destructive force of modern high explosives is such as entirely to revolutionize military tactics, the object of the attacking force being to make itself invisible, and by an extended front offer no target to the enemy, indeed it might almost be said that in the modern art of war more importance is attached to the preservation of the lives of one's own troops than to the destruction of those of the enemy. Certain it is that the carnage of modern warfare, in spite of the infinitely greater efficiency of engines of war, is incomparably small and almost insignificant by the side of the wholesale devastations of the middle ages.

Still more beneficent in its influence on humanity has been the effect of the development of the industrial uses of explosives. By means of blasting powder, and particularly of dynamite, mankind has been enabled to transform the face of the earth. An exhaustive inquiry into the first uses and applications of the explosive which is still commonly called gunpowder, though its employment as a military propellent has been discontinued by civilized countries, still presents fascinating features to the antiquarian.

In the "Handbook on the Manufacture of Gunpowder," by Captain F. M. Smith, R.A., printed by the Government in 1871, gunpowder is stated to have been used in the earliest ages, "principally amongst the Eastern Nations." Captain Smith refers to "a code of Indian laws,[1] supposed to have been compiled in the time of Moses" which contains "reference to cannon and guns," as well as to the claim laid by the Chinese to the early invention of powder; thus, according to the writers who insist on the fabulous antiquity of gunpowder, Schwartz or Roger Bacon, who had hitherto been regarded as entitled to the merit of the invention, had only re-discovered what had been known thousands of years before. Captain Smith, while admitting that substances resembling gunpowder, but composed principally of saltpetre, may have been used in the East at a very early period, considers it extremely improbable, however, for gunpowder proper to have been known and used as such

[1] The Gentoo Laws.

before comparatively modern times. He argues that although the deflagrating properties of saltpetre, which is found as a natural product in many parts of Asia, must have attracted early attention, and although its employment as an ingredient of burning compositions was probably general, it is too much to believe that the use of firearms, which would have given one nation such an advantage over another, should ever have been forgotten after it had once become known. He therefore concluded that the terms used in ancient manuscripts must have received modern interpretations which were foreign to their original meaning, for, as he points out, even if gunpowder were known thousands of years ago, it had little interest until used as a propellent; and as the use of firearms in Europe dates from about the beginning of the fourteenth century, he maintains that their employment in other parts of the globe could not have been general at a much earlier date.

Oscar Guttmann, in "The Manufacture of Explosives," asserts that the Arabians knew of saltpetre as early as the eighth century, but adds that "it is not until the time of Roger Bacon, in the thirteenth century, that we find any mention of the property that saltpetre has of deflagrating with burning bodies." He also discredits the supposed antiquity of gunpowder. That the Chinese did not know of it appears plain to him from the fact that they were frightened when three pieces of ordnance, which the Portuguese of Macao had presented to them, were tried.

With regard to the Hindus, he demonstrates the correctness of Captain Smith's shrewd suspicion as to the inaccuracy of translators, and points out that had the Hindus really invented gunpowder, the inhabitants of Mozambique would very probably have been less alarmed than they were by the report of the guns of Vasco de Gama in 1497, seeing that close trading relations existed between India and these parts, and that the eastern coast of Africa was inhabited by Malays. Professor P. C. Ray, in his "Hindu Chemistry," from a careful study of the question, also comes to the conclusion that the Hindus did not know of gunpowder.

Guttmann adds: "It is equally hard (on the existing evidence) to believe that the Arabians knew of gunpowder as a propelling agent before the year 1313."

He cites from the Annals of the Town of Ghent an entry to the effect that the use of gunpowder was invented in the fourteenth century by a German monk; but considers that although Berthold Schwarz, the Franciscan monk of Freiburg, was without doubt the inventor of firearms, there is nothing to prove that he also invented gunpowder.

Guttmann sums up a very careful and exhaustive review of all the available evidence, and comes to the conclusion that gunpowder was developed from Greek fire and known years before cannon or guns were thought of. The use of purer materials in making it developed its propulsive power and led to the subsequent invention of cannon and guns. The Arabians were the first to make compounds resembling gunpowder about 1280, whilst the idea of utilising the propulsive force inherent in the same, that is the invention of guns and cannon, was originated by Berthold Schwarz, a monk of Freiburg, in about 1313.

Lieutenant-Colonel Henry Hime, R.A., in his "Gunpowder and Ammunition," published in 1904, whilst admitting that the attention of the ancients was naturally attracted by the efflorescences which form on certain stones, on walls, and in caves and cellars, and that the Hindus and nomad Arabs must have noticed the deflagration of at least one of them when a fire was lit on it, points out that these efflorescences consisted of various salts, so similar in appearance and taste, that early observers succeeded in discriminating only one of them, common salt, from the rest. He shows that the radical difference between potash and soda was not finally established by Du Hamel before 1736, and maintains that no trace of saltpetre has hitherto been found anywhere before the thirteenth century; for the Greek alchemists of preceding centuries are silent, and in the earliest recipe we possess for Greek fire, No. 26 of the "Liber Ignium," ascribed to Marcus Graecus (Paris MS. 1300; Munich MS. 1438), there is no saltpetre. Although *sal coctus* is translated in M. Hoefer's "Histoire de la Chimie" by *salt-*

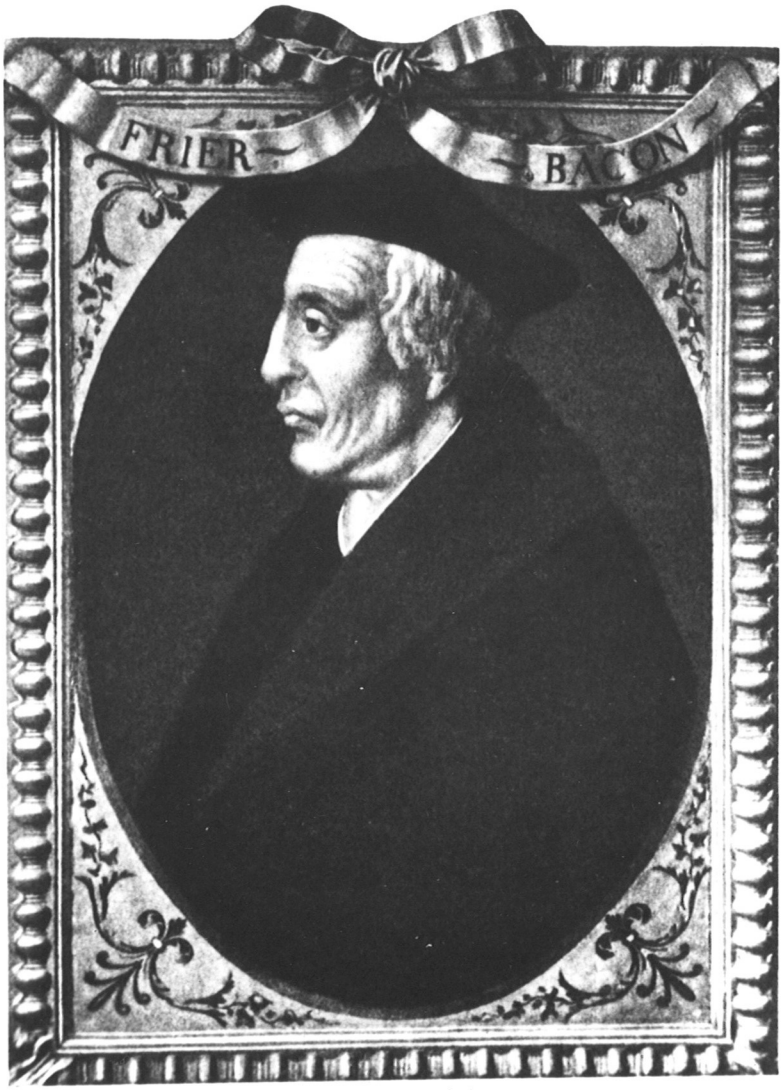

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FIG. 2. ROGER BACON.
(Photograph of a painting at Knole Castle.)

petre; MM. Reinaud and Favé contend that such a rendering was unjustifiable. Colonel Hime then proceeds to the demolition of the theory that the Arabs knew saltpetre in the ninth century by showing how Berthelot had discovered two Gebers; the real original Arab Geber knowing nothing of saltpetre, whilst the other, who was a Western and did, lived about the time of the year 1300. Turning from the Arabs to the Hindus, Colonel Hime finds that there is no word for saltpetre in Sanskrit. Although the Egyptians called it Chinese snow, Colonel Hime does not think this justifies the conclusion that saltpetre was discovered by the Chinese. Friar Bacon, whose "De Secretis" was written before 1249, and Hassan-el-Rammah, who flourished 1275-95, were thoroughly acquainted with the salt. Yet Bacon speaks of it as one would speak of a substance recently discovered and little known.

Space will not permit us to follow Colonel Hime's closely reasoned chain of destructive criticism, nor to reproduce his ingenious reading of Bacon's cryptogram, of which he says that the method Bacon appears to have adopted was that known long afterwards as the "Argyle cipher," of which an example from Thackeray's "Esmond" is given by him. The result is so overwhelmingly conclusive that his reading has received prompt and universal acceptance.

Chapters IX and X are proved by him to give instructions for refining saltpetre, and his interpretation of Bacon's famous anagram in Chapter XI, is equally brilliant. The passage runs as follows:

"Item pondus totum 30. Sed tamen salis petrae LURU VOPO VIR CAN UTRIET sulphuris; et sic facies tonitruum et coruscationem, si scias artificium. Videas tamen utrum loquor aenigmate aut secundum veritatem."

Which interpreted into English, and omitting the anagram, means:

"Let the total weight (of the ingredients) be 30. However, of saltpetre . . . of sulphur; and with such a mixture you will produce a thundering noise and a bright flash if you know 'the trick.' You may find (by actual experiment) whether I am writing riddles to you or the plain truth."

Colonel Hime then re-arranges the letters of the anagram as follows:

RVIIPARTVNOUCORULVET,

or, since u and v are interchangeable, makes the whole passage in the original read:

"sed tamen salis petrae recipe vii partes, v novellae coruli, v et sulphuris" etc., that is—

"but take 7 parts of saltpetre, 5 of young hazelwood, and 5 of sulphur," etc.

But Colonel Hime does not base Bacon's claims on these anagrams and shows on grounds independent of the steganogram and the anagram, that Bacon was in possession of an explosive. Colonel Hime, while destroying Marcus Graecus, whose tract he says was the work of neither one author nor one period, and of whom he concludes that he was "as unreal as the imaginary Greek original of the tract which bears his name," does not claim for Bacon more than that he discovered but did not invent gunpowder; and maintains that though he knew it exploded, Bacon was not aware of its projective force.

This conclusion, while amply vindicated, will hardly satisfy the adherents of Schwartz, who will no doubt continue to maintain that the discovery of gunpowder as an incendiary only was of comparatively small utility, and that by burying his invention in a cipher, Bacon had forfeited the gratitude of humanity. At least, it does not appear that Bacon's invention was of great benefit to his own country, for previous to the reign of Queen Elizabeth most of the gunpowder used in England was imported from abroad. John Barbour, Archdeacon of Aberdeen, writing his metrical life of Robert Bruce in 1375, says describing the invasion of Scotland by Edward III in 1327,

Twa noweltys that dai thai saw,
That forouth in Scotland had been nane,
Tymmris for helmys war the tane,
That thaim thoucht than off grete bewte
And alsua wondre for to se:
The tothyr crakys war off wer,
That thai befor herd nevir er.

If Edward III used "crakys" of war in 1327, and Schwarz is to have the credit claimed for him, there seems to be no alternative but to accept the theory adopted by Colonel Hime and expounded in his paper on "Our earliest Cannon" before the Royal Artillery Institution in 1900. He there gives the date of Schwarz's invention as 1313, as in the Ghent annals, and shows that in 1314 the Commercial Records of Ghent contain more than one entry to the effect that guns and powder had been despatched during that year to England.

In the plate on p. 13 is shown a bottle-shaped mortar (Hime calls it a dart-throwing vase), reproduced from an illuminated Latin MS. belonging to Christ Church, Oxford, dated 1326, and dedicated by its English author, Walter de Millemete, to Edward III.

When the Scotch defended Berwick against Edward II, in 1319, the soul of the defence was John Crab, "a Flemyne of gret subtilte," Peter van Vullacre, who had been "Maitre des ribau dequins" at Bruges in 1339, took service with the English force which was to have invaded France in 1345, but did not actually set out until 1346; and he it was who in all probability commanded the guns at Cressy, for which Napoleon III gave us credit.

Whatever the date of the invention of cannon, artillery was evidently known in 1380, because Chaucer, in his "House of Fame," written at that date, has the following lines:

> As swift as pelet out of gunne,
> When fyr is in the poudré runne.

There is unquestionable testimony that cannon, both brass and iron, were employed on board English ships of war in 1338, testimony at least sufficient to satisfy General Sir H. Brackenbury, as a reference to vol. iv, p. 291 of the "Proceedings of the Royal Artillery Institution" will show. Two years later the English Navy employed guns at the battle of Sluys, but without effect.

The gun depicted by Froissart, which may be taken to be a fairly accurate representation of the type used at Cressy, shows a great

advance on the *pot de fer* of 1326-7; it is a breech-loader which should certainly have fired iron or leaden case balls, and may even have fired stone shot the size of the bore.

To return to powder, the first distinct reference to gunpowder occurs in 12 Edward III, 1338, when it is mentioned in an indenture. Francis Grose in his "History of the English Army" (1801), makes us suspicious of these early records, and shows how Cotton, who in his "Abridgement of the Records of the Tower of London," says that "pardon was made out 14 Edward III to Thomas de Brookhall for a debt of 32 tons of powder," misread the original entry where the word *pomadre*, meaning cyder, is used.

William Henry Hart of the Public Record Office, in his very interesting pamphlet on the "Early Manufacture of Gunpowder in England," published in 1855, tells us that John Cook, clerk of the king's great wardrobe, in an account dated 10th May, 1346, stated that 912 pounds of saltpetre and 886 pounds of quick sulphur were supplied to the King for his guns.

The old method of obtaining saltpetre was to collect vegetable and animal refuse containing nitrogen, the sweepings of slaughter-houses, weeds, etc., into heaps and to mix this with limestone, old mortar, earth and ashes. These heaps were sheltered from the rain, and kept moist from time to time with runnings from stables and other urine.

As late as in the reign of James I (1624), we find in an indenture between the King and Thomas Warricke, Peter Sparke, Michael Townshend and John Fells, the statement that "for making of the saltpetre which hath been formerly and now is made . . . it has been found a matter of mere necessity to dig houses, cellars, vaults, stables, dovehouses and such like places, wherewith divers of his Majesty's subjects have found themselves grieved." We are also informed that the conveyance of the liquors, vessels, tubs, ashes, etc., from place to place in carts had been a frequent source of nuisance and litigation.

The above persons purporting to have invented a new process for making saltpetre undertake to make it "as good and perfect as any

FIG. 3. FROM WALTER DE MILLEMETE'S MANUSCRIPT. A.D. 1326.

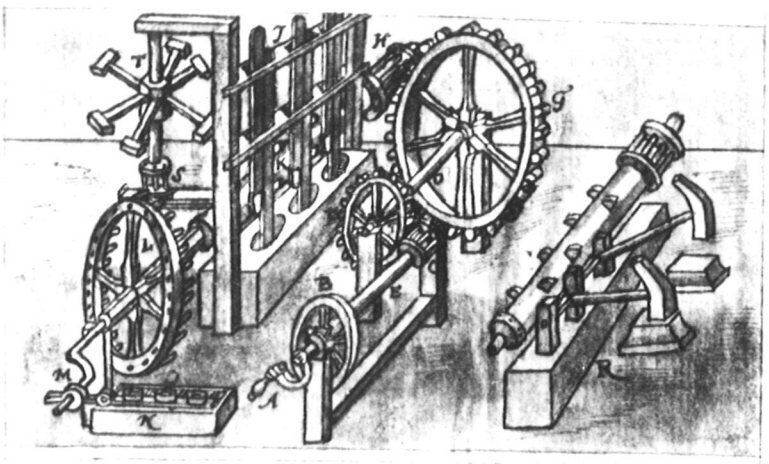
(By kind permission of the Dean of Christ Church.)

hath formerly been, and shall be vented at cheaper and easier rates than formerly his Majesty or his loving subjects have paid for the same, which said saltpetre as His Majesty is informed is to be or may be made of an artificial mixture or composition of chalk, all sorts of limestone and lime, marl, divers minerals, and other nitrous mines and other kind of ordinary earth, street dirt, or rubbish, stable dung, emptying of vaults, the excrements of all living creatures, their bodies putrified, all vegetables putrified or rotted, or the ashes of them, and these or any of these mixed together in proportion as they may be most conveniently had, and shall be found most useful in such places where the said works shall be thought fit to be erected, which said artificial mixture or composition of any or all the foresaid ingredients is often times moistened with urine of men and beasts, petre, or nitrous wells, and springs, and all other concrete juices and blood of all sorts as can be gotten, and shall be fit and convenient for it, and divers times turned and removed, by which means the mixture in time digesteth, fermenteth, and ripeneth, from whence there is engendered the seed or mine of saltpetre which afterwards is to be extracted with common water, urine, the water of petre or nitrous wells, and springs, and then either breathed away in the sun or air, or stoved with gentle heat or boiled with a stronger fire with his proper additament of ashes, lime, and such like for separating the common salt and other mixtures naturally growing in the liquor and afterwards refined into perfect saltpetre."

The King then granted the patentees licence to exercise their invention for a term of twenty-one years and to set up houses for preparing the artificial earth, etc.

On 26th December of the same year "was issued a proclamation, commanding that no dovehouses or cellars be paved, except that part of the cellars where the wine and beer is laid, in order that the growth of saltpetre might not be obstructed." (Patent Roll, 22 James I, part 4, No. 9 dorso.)

In March, 1378, in the first year of Richard II, Thomas Norwich

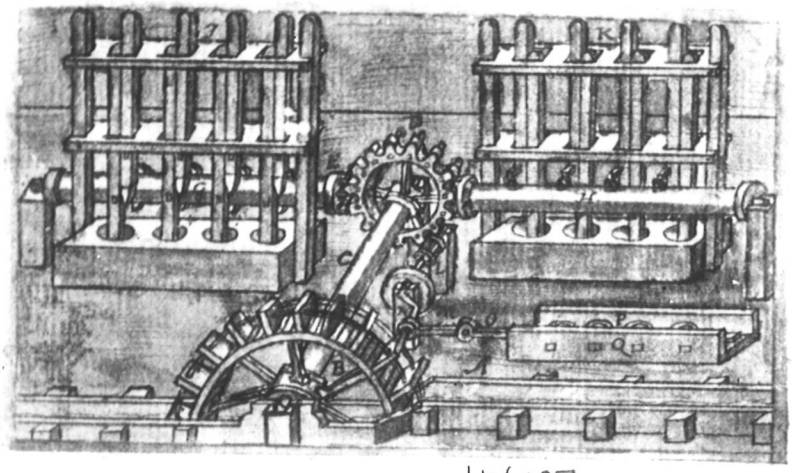


This is a pouder mill, the mouement whereof is of such faculitie, that after it bee once in his mocion The workman which turneth the said mill, may intend any other busines ye $\frac{1}{4}$ of an hower or more, and yet the mill, shall not ceasse his motion, but both beat the pouder, and corne it all at one instant. for the handle A being moued the wheele B and the axletree E with the lanterne C moueth also which lanterne C mooueth the wheele F the axletree O and the wheele G which wheele G moueth the lanterne H the axletree K the wheele L and the wrest and branch M The axletree M moueth the stampers J by meanes of the cogges The wheele L moueth the lanterne S wch beareth the swingle T about which swingell, by reason of the weight at the endes of the barres causeth the easie mouement of the said mill The wrest M being fast to the branch M causeth the easy mouement of the sieue O which bee in the case N standing upon the branch M by meanes whereof the pouder is corned, the figure R sheweth that the mouement may bee adapted to an iron mill a fulling mill or a paper mill or an oyle mill, as well as a pouder mill.

FIG. 4. ENGLISH STAMP MILL IN THE SIXTEENTH CENTURY.

was ordered to buy saltpetre, sulphur, and charcoal to be sent to the Castle of Brest, and in 1414 Henry V decreed that no gunpowder should be taken out of the Kingdom without special licence. Henry VI in 1457 appointed as Master of the Ordnance for life John Judde, merchant of London, who was skilled in the devising of warlike instruments, and had made at his own expense sixty guns called serpentines, and twenty tons of "stuff for gunpowder of saltpetre and sulphur."

We find in 1512 a Th. Hart making gunpowder in Rochester Castle, and in 1514 a house let by the new Hospital of our Lady Bishopsgate Without for the making of gunpowder; further, the appointment of Hans Wolf, a foreigner, to be one of the King's gunpowder makers in the Tower of London and elsewhere, and in 1531 Thomas A Lee, one of the King's gunners, to be principal searcher and maker of saltpetre. In 1555 Henry Reve erects a gunpowder mill on a parcel of pasture ground called "The Crenge," in Rotherhithe, and in 1559 there are already tenders by the powder makers for the supply of gunpowder. In 1562 John Thomworth of Waltham is in treaty, on behalf of Queen Elizabeth, for the purchase of saltpetre, sulphur and bow staves for barrels, and presumably a powder-mill existed there at that time. In 1562 three gunpowder makers, Bryan Hogge, Robert Thomas and Francis A Lee tendered for the supply of gunpowder, the same Lee being described in the particulars of leases of Elizabeth in 1578 as gunpowder maker to the Queen, and having a gunpowder mill and pond "in the tenure of Thomas Lee, deceased and now of Francis Lee, his son, in Rotherhithe, near the Thames." This was probably the mill erected by Reve in 1555. It is to be noted, however, that in a petition in 1575 Lee calls himself "Francis Leigh, gunpowder maker to the Council," and says that he and his father and brother have been for fifty years "The greatest dealers therein, and he has all the implements." The gunpowder mill at Leigh Place, near Godstone, in Surrey, which existed about 1560, and was later on the property of the Evelyns, may well have also been erected by the Lees or Leighs. In 1576 one John Bovyat seems to



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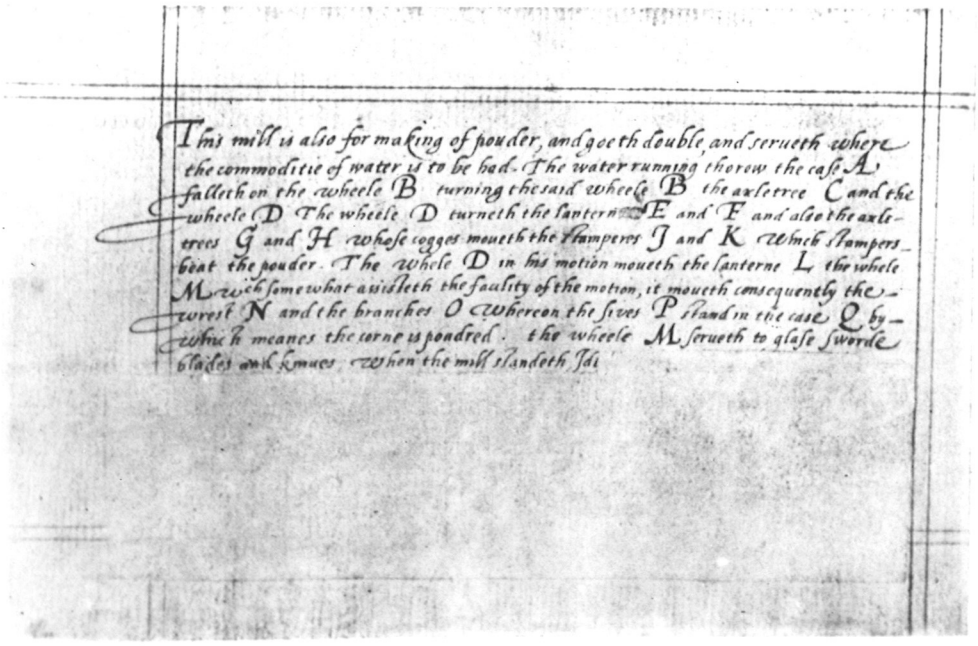

FIG. 5. ENGLISH STAMP MILL IN THE SIXTEENTH CENTURY.

have received a patent for making saltpetre and gunpowder "from stone, mineral and other substance not now used therein," and in 1580 one Sebastian Orlandini and John Smithe seem to have erected clandestinely a glass furnace in a gunpowder mill in Ratcliffe.

Until the latter end of Queen Elizabeth's reign there had been free trade in gunpowder, but then as now, the country became subject to war scares, and the menacing attitude assumed by Spain compelled the Government to take a serious view of the question of national defence. Commissions or monopolies were therefore granted to private persons for the manufacture of gunpowder; and so we find that in 1588 George Evelyn, Richard Hills and John Evelyn were given licence and authority for the term of eleven years "to dig, open and work for saltpetre," anywhere they liked except in the City of London and two miles outside it and the northern counties of York, Northumberland, Westmoreland, Cumberland, and the Bishopric of Durham. George Constable was given in 1589 a similar licence for these northern counties. John Grange and Ralph Hockenhull were also engaged in making gunpowder, and in the following year Thomas and Robert Robinson were given the right over London and Westminster. These patentees or monopolists appointed their own saltpetre men under their respective licences to dig and search for saltpetre, and to call upon the local authorities to provide carriage for the liquors "fit for making saltpetre." These saltpetre men often abused their privileges and were hated and abhorred by the rest of the community, their conduct frequently giving cause for litigation.

The Evelyns appear to have been the first manufacturers of gunpowder on a large scale in the United Kingdom, and the licence conferred on the Robinsons was transferred to them in 1596, so that they practically held the monopoly. George Evelyn is said to have learned the art in Flanders, and was the grandfather of the famous John Evelyn.

There are numerous covenants on record wherein various members of the Evelyn family undertake in conjunction with partners of different

names to deliver yearly to the Tower of London certain quantities of gunpowder. In 1620 James I granted a license "to make and work for saltpetre and gunpowder" to George, Marquis of Buckingham, High Admiral of England, George, Lord Carew, Master of the Ordnance, and Sir Lionel Cranfield, Master of the Court of Wards and Liveries. In the letters patent, dated 24th January, reference is made to the "many abuses of sundry inferior persons" who had been engaged in the saltpetre industry, and the frequent complaints to which these had given rise; and to the determination to import this material from abroad in consequence, but "finding that the same cannot be performed wholly "from foreign parts without much inconvenience," it was deemed expedient, whilst not excluding foreign importations, "to continue the making thereof using such vigilance and care in the ordering and managing thereof as may best tend to the reformation and repressing of those enormities and abuses wherewith such inferior persons did most infest our loving subjects."

In 1623, ostensibly for the prevention of weak or defective powder, a proclamation was issued by James I prohibiting its manufacture, as well as that of saltpetre, except under the King's commission, and also its export, and directing that all gunpowder be proved and marked by the sworn proof-master.

At last in 1626 we find the East India Company importing saltpetre. The Company erected powder-mills in Surrey, and its renewed Charter in 1693 stipulated for the annual provision of 500 tons of saltpetre to the Ordnance. From this time forward we hear of no difficulty, at least in England, of obtaining this chief ingredient of gunpowder.

Guttmann is of opinion that gunpowder was originally prepared in stone mortars by hand, and that as the consumption increased, millstones were used. That the quantities were very small at first, is shown by the fact that the King issued a writ, dated 25th November, 1346, commanding that all the purchasable saltpetre and sulphur should be bought, and that the quantity thus obtained did not amount to more

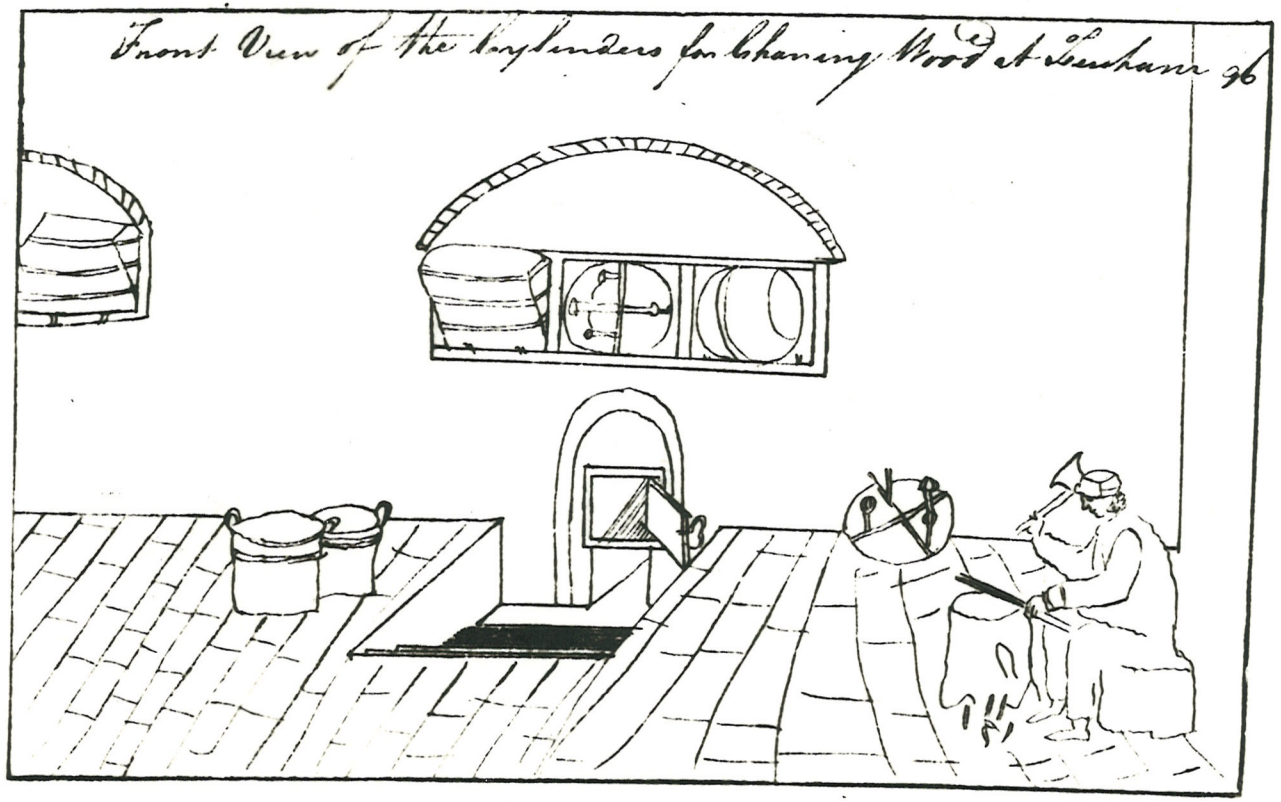

FIG. 6. CHARCOAL CYLINDERS IN 1798. FRONT VIEW.

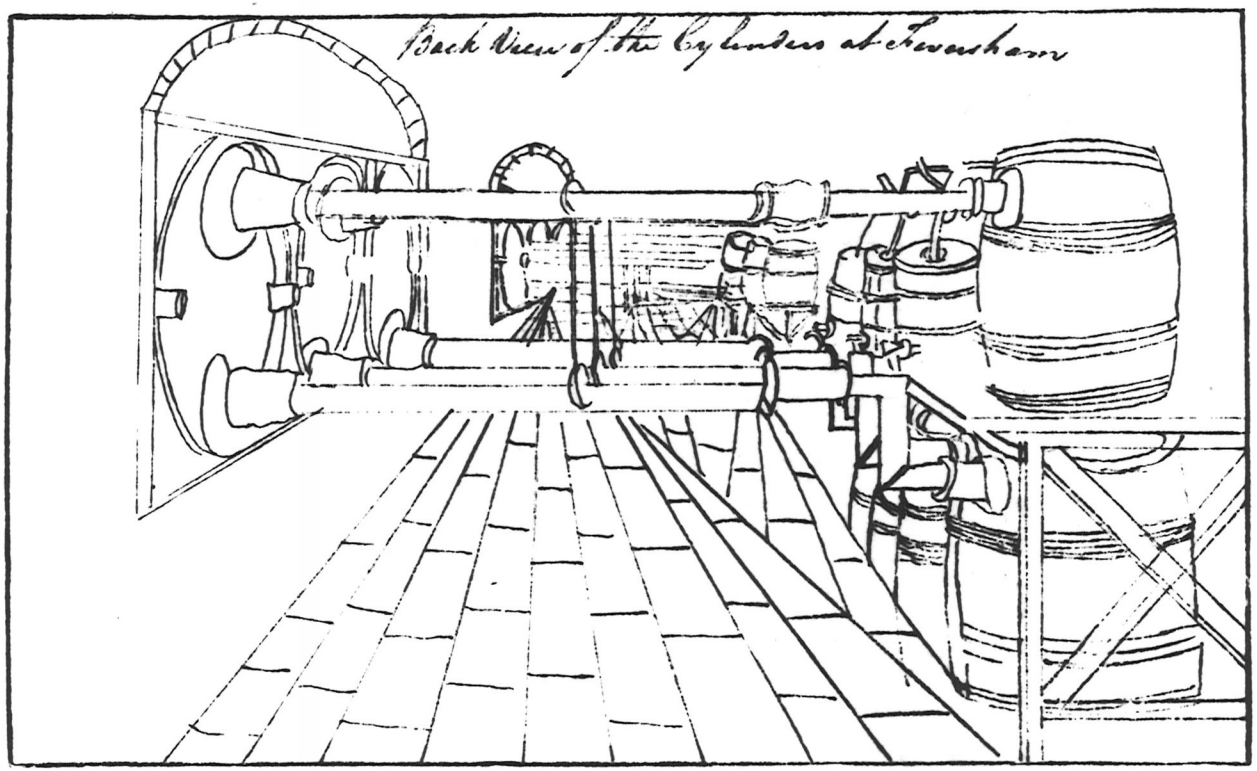

FIG. 7. CHARCOAL CYLINDERS IN 1798. BACK VIEW.

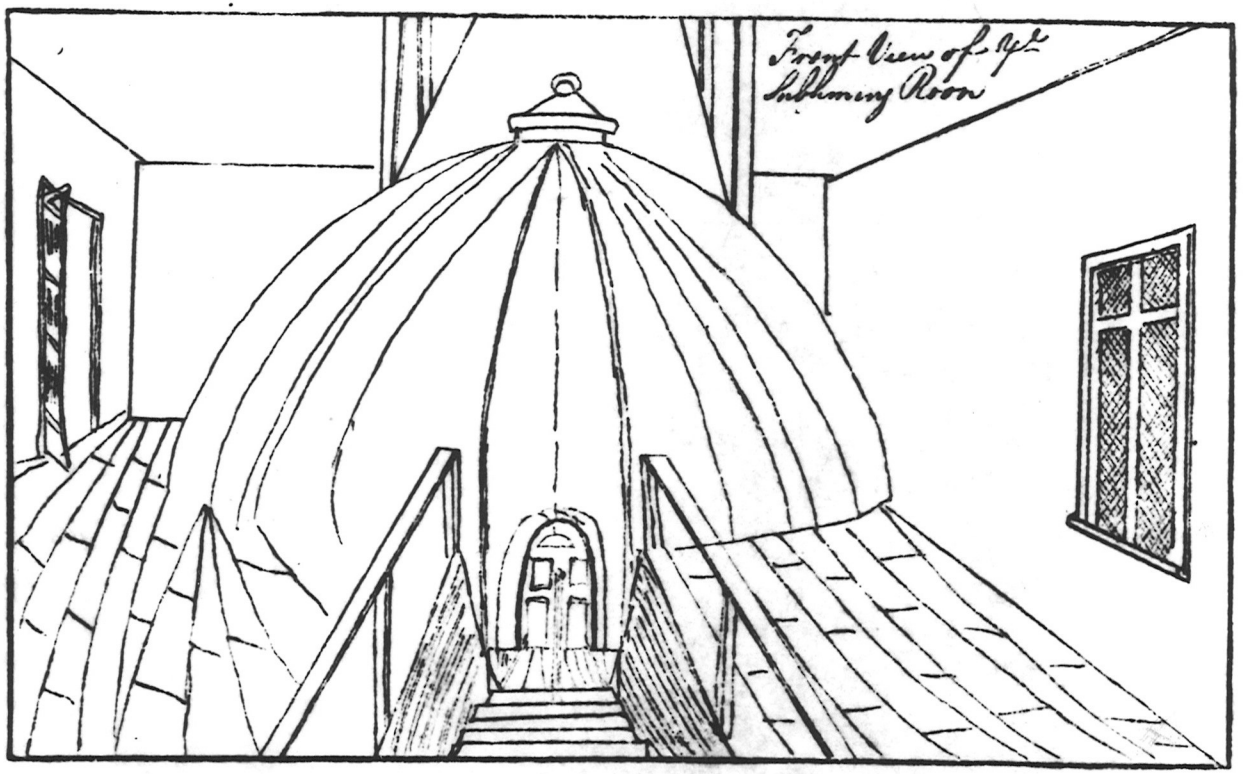

FIG. 8. SULPHUR SUBLIMING CHAMBER IN 1798. FRONT VIEW.

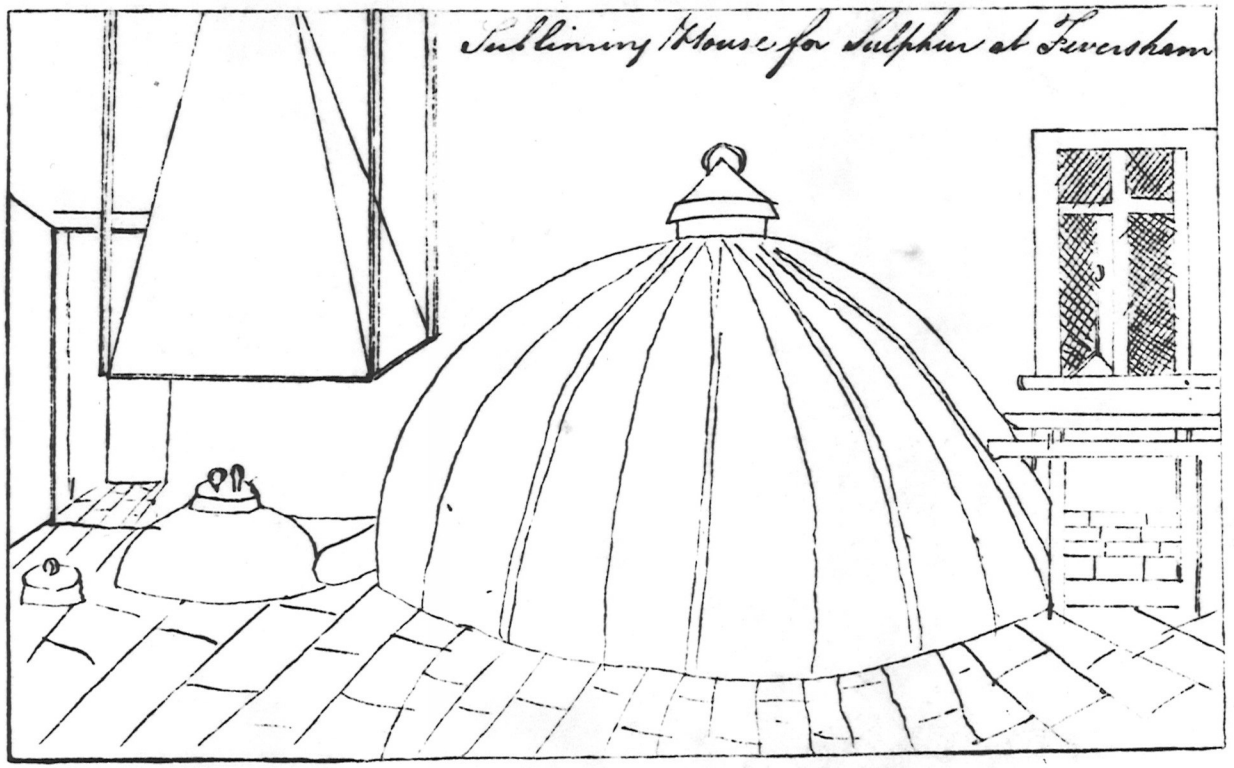

FIG. 9. SULPHUR SUBLIMING CHAMBER IN 1798. SIDE VIEW.

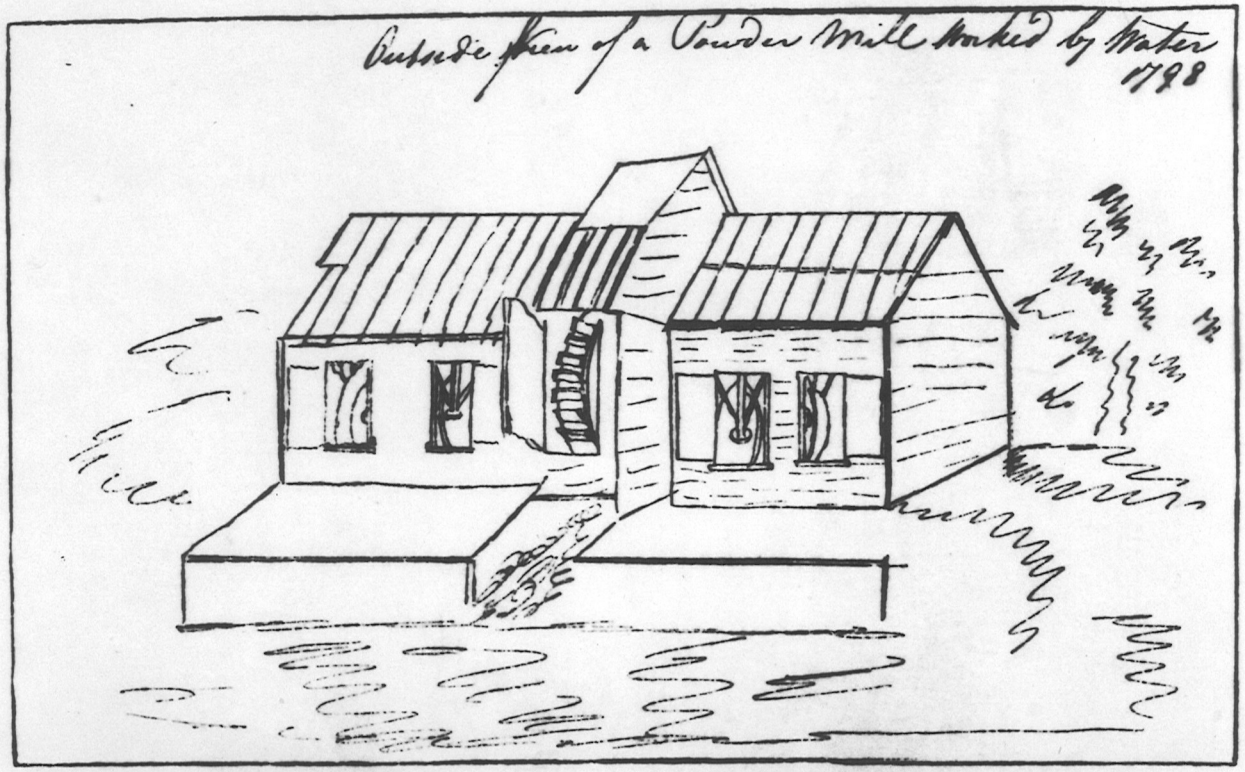

FIG. 10. POWDER MILL IN 1798. OUTSIDE VIEW.

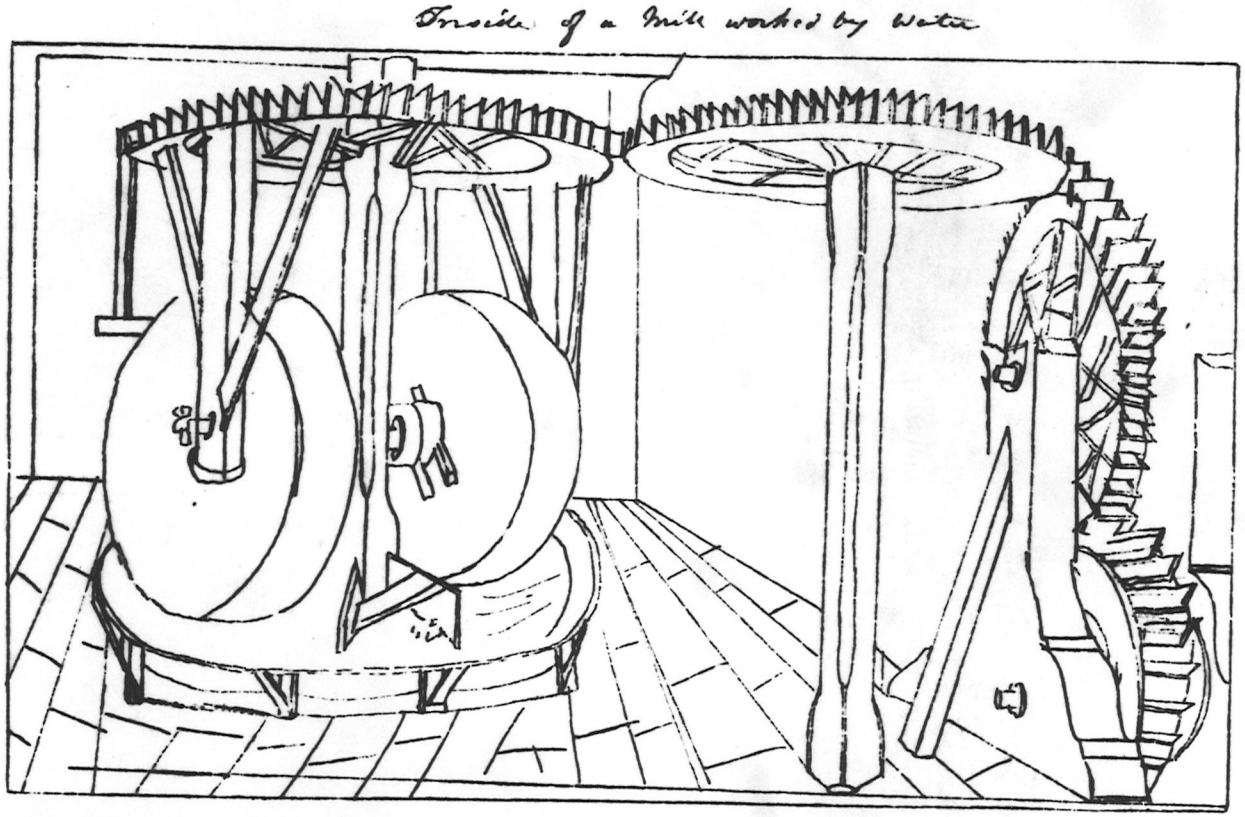

FIG. 11. STONE INCORPORATING MILLS IN 1798.

than 750 pounds of saltpetre and 310 pounds of quick sulphur; whilst in the September of the following year a further quantity of 2,021 pounds of saltpetre and 466 pounds of quick sulphur was purchased.

It may be interesting to inquire into the ingredients of the earliest gunpowder. Bacon's recipe, as interpreted by Colonel Hime, gives the following proportions of the ingredients in one hundred parts:

Saltpetre 41.2, Charcoal 29.4, Sulphur 29.4.

The next complete recipe is given by Dr. John Arderne, of Newark, who commenced to practise as a surgeon before 1350. He says: "Prenez j.li. de souffre vif; de charbones de saulx (i. weloghe) ij. li; de saltpetre vj. li. Si les fetez bien et sotelment moudre sur un pierre de marbre, puis bultez le poudre parmy vn sotille couerchief: cest poudre vault à gettere pelottes de fer, ou de plom, on d'areyne. oue vn instrument que l'em appelle gonne." This works out in hundred parts at:

Saltpetre 66.6, Charcoal 22.2, Sulphur 11.1.

This recipe, while interesting, as being one of the earliest authentic prescriptions on record, is, however, discredited by Hime, who describes it as a literal translation of a recipe for rocket composition given by the apocryphal Marcus Graecus, and points out that its proportions are entirely out of keeping with those of the French powder of 1338, which, however, is incomplete, the quantity of charcoal being omitted. It is interesting to compare this composition with the oldest German one contained in "Cod. membr. Saec. XIV, Rothenburg, o. T." It was:

Saltpetre 58.2, Sulphur 23.6, Charcoal 18.2.

According to Nathaniel Nye ("The Art of Gunnery," 1648), gunpowder was made in the following proportions:

In 1380. Saltpetre, brimstone, and charcoal, in equal parts.
In 1410. Saltpetre 3 parts, brimstone 2 parts, charcoal 2 parts.

In 1480. Saltpetre 8 parts, brimstone 3 parts, charcoal 2 parts.

In 1520. Saltpetre 4 parts, brimstone 1 part, charcoal 1 part.

In 1647. Pistol powder: Saltpetre 6 parts, brimstone 1 part, charcoal 1 part.

Musket powder: Saltpetre 5 parts, brimstone 1 part, charcoal 1 part.

Cannon powder: Saltpetre 4 parts, brimstone 1 part, charcoal 1 part.

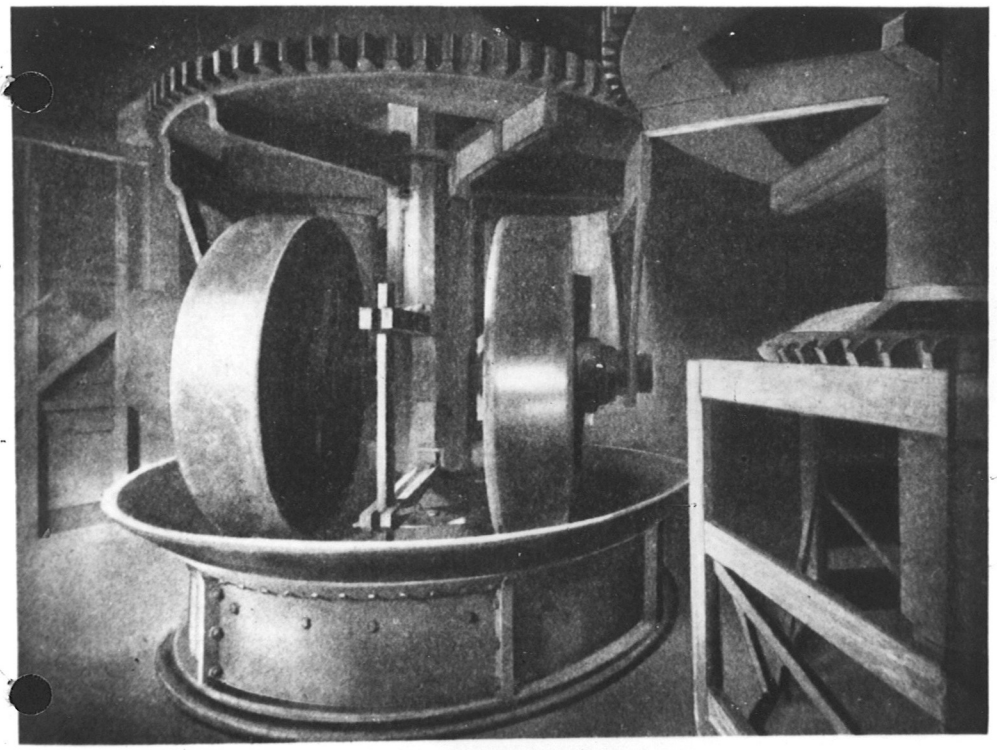

FIG. 12. STONE INCORPORATING MILLS AT WALTHAM ABBEY.

Colonel Hime gives an interesting chronological table of English gunpowder, in which, however, he includes Dr. Arderne's powder as well as Bacon's. We shall get a juster view of the constancy of the proportions by eliminating these two columns. His table would then

show the steady increase of saltpetre, the most important of the ingredients, thus: for cannon powder

	1560. (Whitehorn.)	1647. (Nye.)	1670. (Turner.)	1742. (Robins.)	1781. (Watson.)
Saltpetre . .	50.0	66.6	71.4	75.0	75
Charcoal . .	33.3	16.6	14.3	12.5	15
Sulphur . .	16.6	16.6	14.3	12 5	10

An equally interesting investigation of the prices of gunpowder calculated on the prices of the raw materials, leads the same author to the conclusion that English powder cost, in 1378, 1*s.* 3⅔*d.* per pound, equal to about 11*s.* 4½*d.* in current coin of our own times. The other prices are quoted from Thorold Rogers's "History of Agricultural Prices," and mark a steady decline from 1*s.* in 1462, equal to about 10*s.* to-day, to 10¾*d.* in 1695, and 7*d.* in 1865. The introduction of corned powder brought with it a slight increase of price; but when the concomitant fall in the purchasing power of money is taken into consideration, the price of 1*s.* 1*d.* per pound in 1595 compares favourably from the point of view of the purchaser with that of 10*d.* in 1482. According to Hart, the price of powder seems to have fluctuated between 1*s.* and 10*d.* in the sixteenth century. The high price of gunpowder was largely, if not entirely, due to the difficulty of obtaining, and the consequent dearness of, saltpetre.

The gunpowder in use at the time was commonly called Serpentine Powder, and was merely a loose mechanical mixture of three substances, and was necessarily more or less dusty or crumbly in nature. Its combustion was slow and irregular, and much gas escaped through the vent, so that a low velocity was imparted to the shot, with the result that the gunners made but poor practice.

The obvious remedy for these evils was of course to corn the powder. It is not surprising therefore that the old fireworks books already mention lump powder, and Colonel Hime asserts that long before 1560 it was in use for hand-guns in England. While its rapid combus-

tion caused little or no waste of gas through the vent, and the resultant greater strength enabled 2 lb. of corned to do the work of 3 lb. of serpentine powder, it was at first too strong for cannon, and Whitehorn represents that, if used in pieces of ordnance "without great discretion, it would quickly break or marre them."

Commenting on the lawlessness as to the proportions of the ingredients, in what he calls the ancient period, Colonel Hime contends that the introduction of corning made confusion worse confounded, the size of the grain being variable. However, during the second half of the fifteenth century, the suitability of large-grained powders for big guns was discovered, and in the seventeenth century we already find three or four kinds of sieves in use, differing in the size of their meshes, so that the coarseness of the grain could be graduated to suit the size of the gun for which the particular powder was required.

With regard to the manufacturing process, the oldest method of mixing the ingredients of gunpowder was with mortar and pestle by hand, later the pestle was suspended from a spring beam and ultimately stamp mills were introduced, driven at first by hand, and later by horses or water-power. Two illustrations of such mills, from a book in the possession of Messrs. E. G. Hulmè and Rhys Jenkins, are reproduced on pp. 15 and 17, together with the quaint explanation contained in the book.[1] Incorporating mills were also used at an early date, and the use of stamp mills, except for fine sporting powder, was prohibited in this country on account of their danger by 11 George III, cap. 61 (1772).

We have been fortunate in finding a MS. book, evidently compiled by John Ticking, Master Worker of the Royal Faversham Mills in the year 1798, now owned by Messrs. Curtis's and Harvey. It is beyond the scope of this book to copy in detail the regulations and proof for the manufacture of powder, as given in these notes. It

[1] The hammer mill, R on Fig. 4, represents an iron hammer; but it is well known that similar stamps were used by the Cossacks, and the illustration is very much like that published in Siemienowicz's "Great Artillery," which was translated into English.

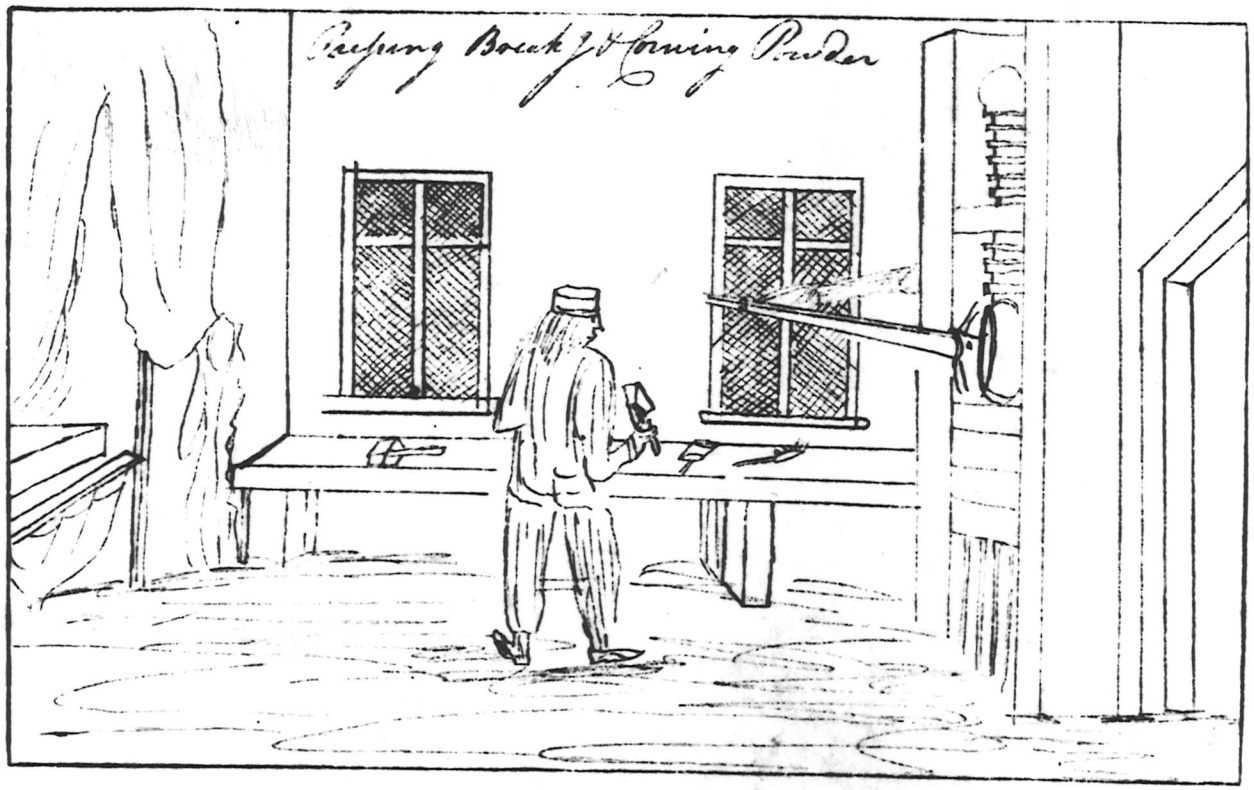

FIG. 13. PRESSING, BREAKING AND CORNING POWDER IN 1798.

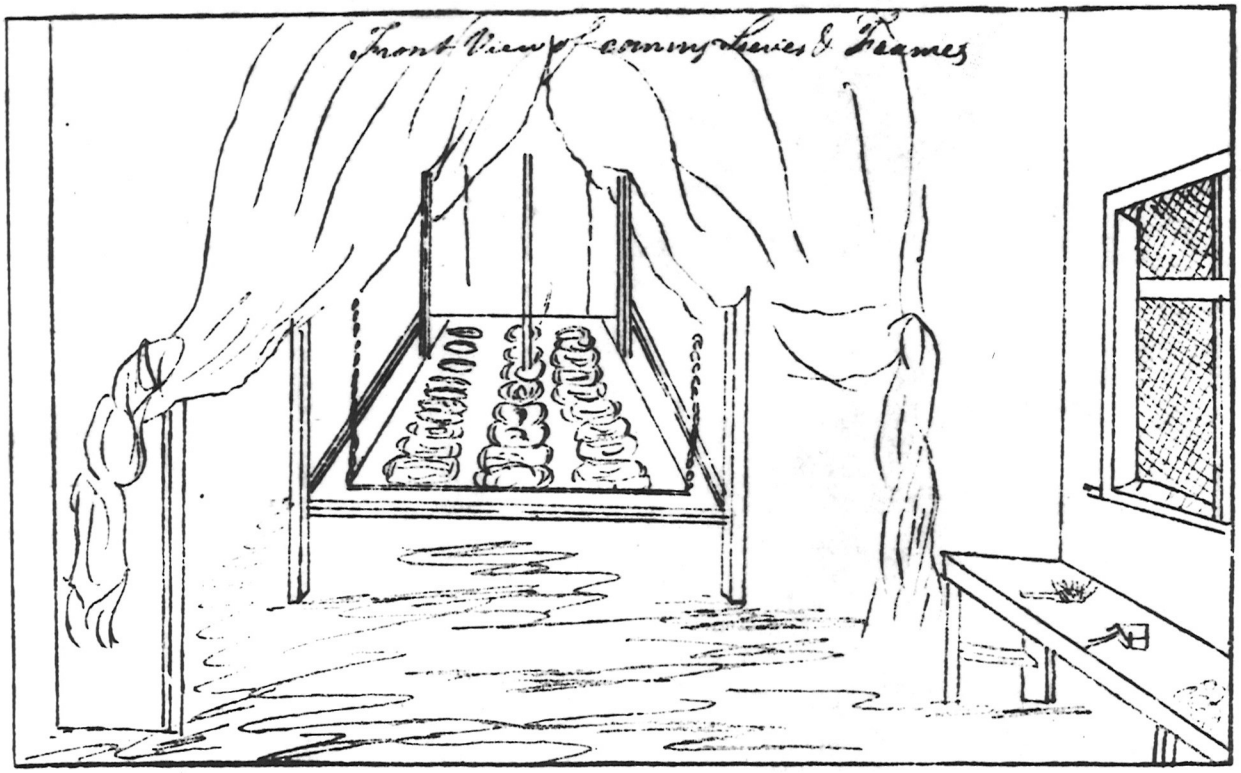

FIG. 14. CORNING-SIEVE IN 1798.

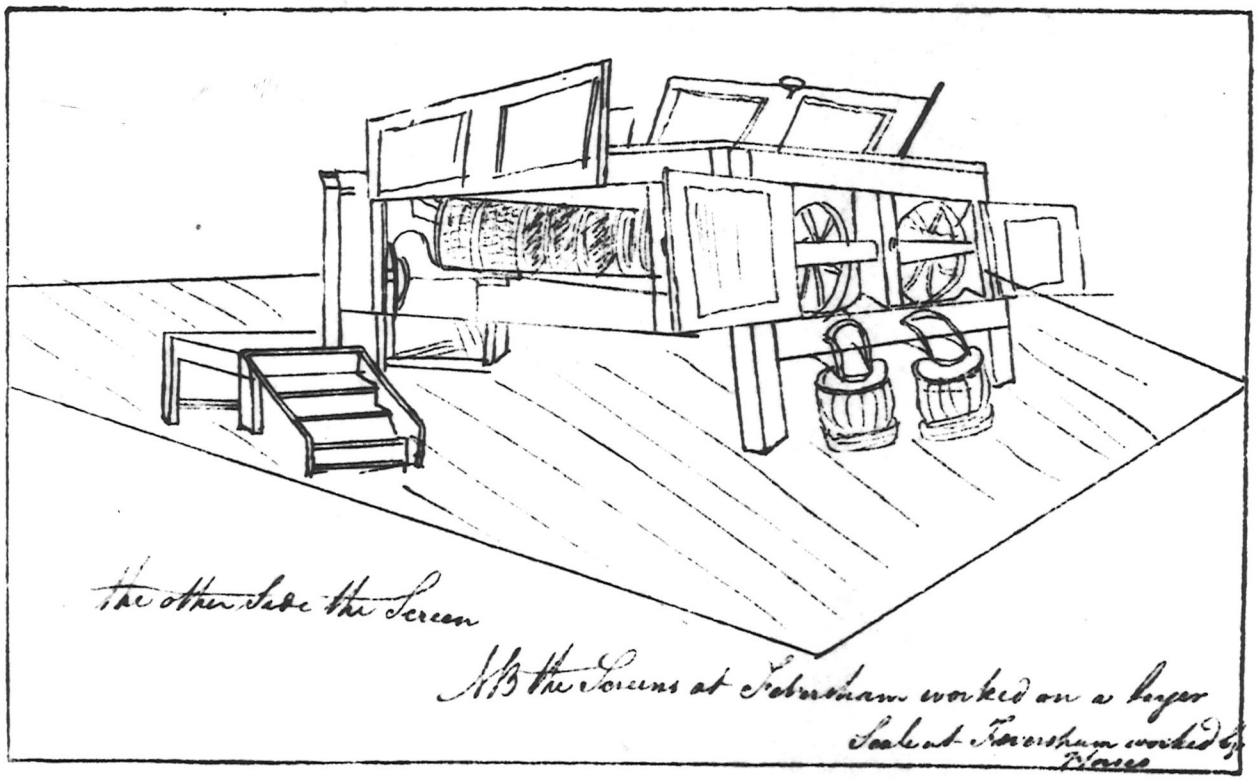

FIG. 15. SIFTING-SCREEN IN 1798.

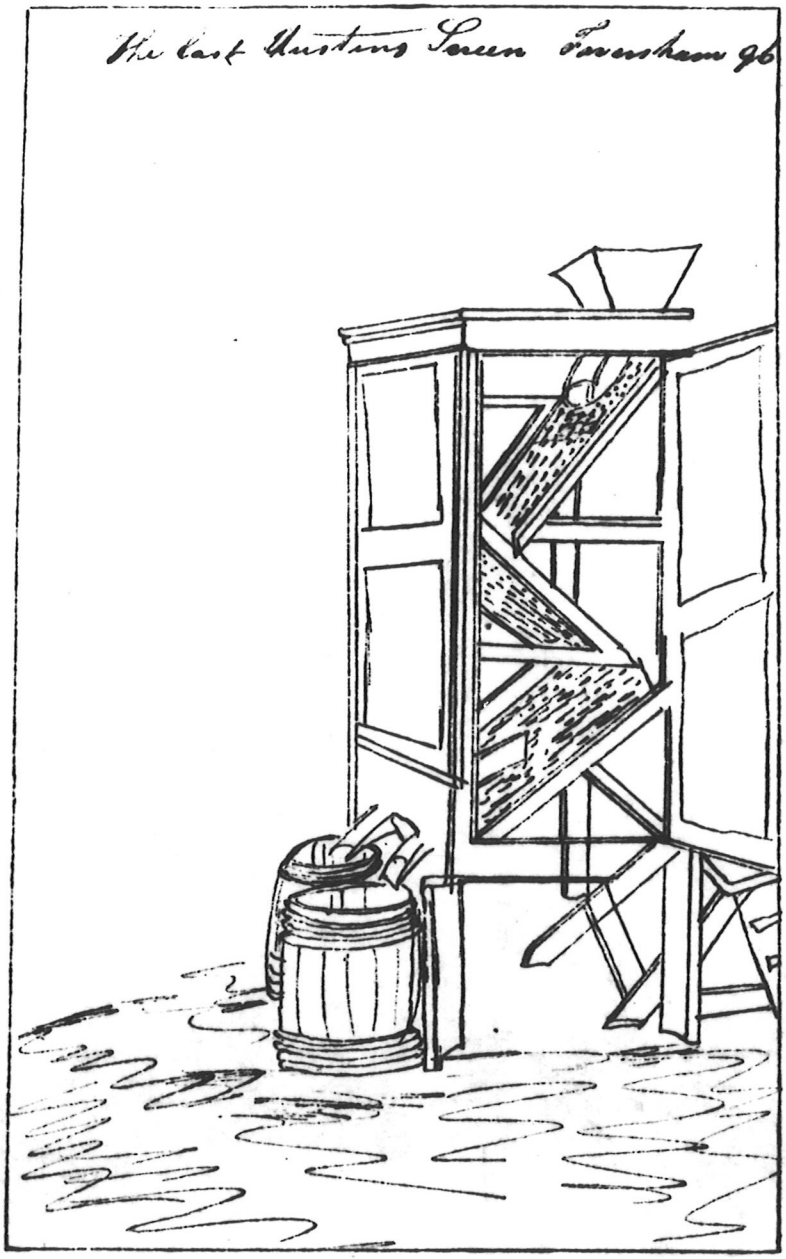

FIG. 16. DUSTING-SCREEN IN 1798.

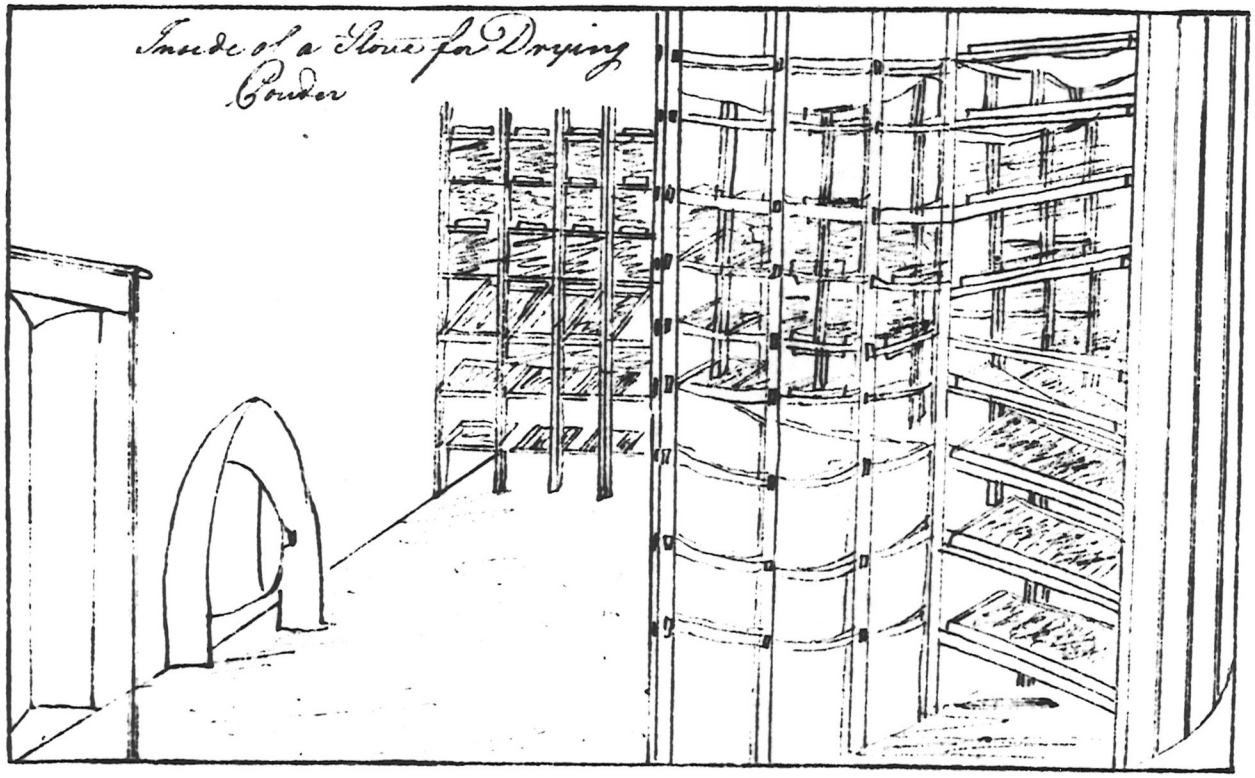

FIG. 17. INTERIOR OF A DRY STOVE IN 1798.

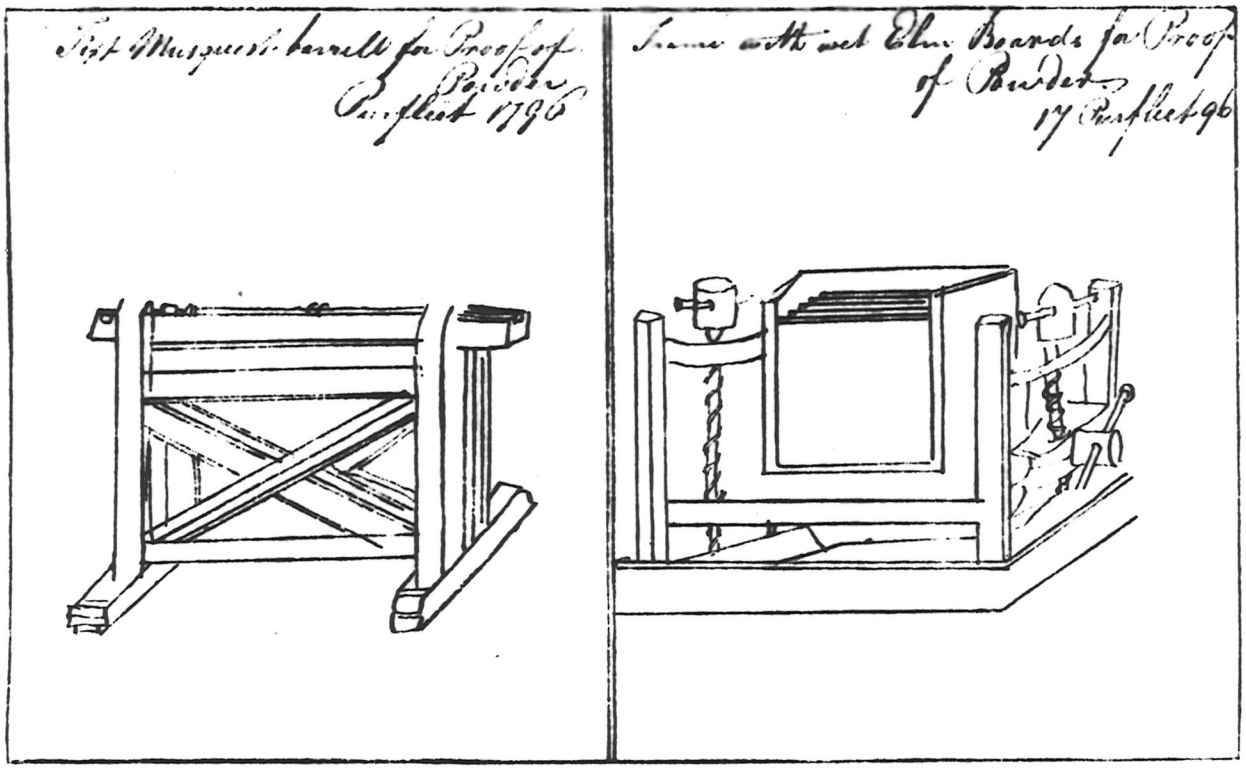

FIG. 18. GUN REST AND PROOF BOARDS IN 1798.

seems that at that time three kinds of "King's Powder" were made, and respectively marked L G in red for a strong powder, L G in blue denoting a powder which was uniform and very durable, and L G in white, one that in general was stronger than the blue, but more liable to become dusty.

Charcoal was already made in cylinders as shown in Fig. 6, and the products of distillation were recovered at the back of the cylinders both from the top and the bottom, as shown in Fig. 7. The sulphur was sublimed in a large chamber, of which views are given in drawings 8 and 9, and the powder was worked in incorporating mills, two of which were attached to a water-wheel, as shown in Fig. 10. The view of the incorporating mill is given in Fig. 11, and it shows the complicated way in which the power was transmitted from the water-wheel to the mills by means of cog-wheels. The incorporating mills had stone runners, and a photograph of such a mill still in existence at Waltham Abbey is shown in Fig. 12. The incorporated powder was put into a screw press and the press cake broken up by hand as shown in Fig. 13; after this the powder was corned in a corning-sieve, shown in Fig. 14, and reeled as shown in Fig. 15. The dusting-screen, as used in Faversham, after the drying, is shown in Fig. 16.

The drying-house shown in Fig. 17 is very interesting. The room was semi-circular, and the powder laid out on racks arranged along the wall in a semi-circle, with a circular rack in the middle. The heat was communicated to the room by means of a stove in the shape of an iron pot set into the wall in an adjoining room, in such a manner, that the bottom was inside the drying-room, and the coal was put into it from the adjoining room. A sheet of copper was placed over the pot when the powder was charged or discharged, and this was protected by a canvas screen.

Fig. 18 shows on the left side a fixed musket barrel, from which a steel ball is shot through 17 wet elm boards shown on the right hand side of the illustration; these were $\frac{1}{2}$ inch thick and $\frac{3}{4}$ inch apart, the musket barrel being 39 ft. 10 in. away.

FIG. 19.—CHARLES BERWICK CURTIS.

The King's powder usually shot through 15 or 16 boards.

Further improvements in the manufacture of gunpowder were made by Colonel Sir William Congreve, who worked out many of the modern manufacturing details.

Until an instrument was devised for measuring the comparative strength of different powders, no standard for the proportions of the ingredients and the size of the grain could be established. Bourne's "engine or little boxe" (1578), is believed to be the earliest instrument of this kind, but is described as "wretched." It consisted of a small metal cylinder in which the powder was ignited, and was fitted with a heavy hinged lid held in position at the point to which it was raised by means of iron teeth. The angle through which the lid was raised by the explosion indicated the strength of the powder. In the instrument described by Furtenbach in "Halinitro Pyrbolia" in 1627, the lid of the cylinder is movable along two vertical wires, and is also kept in position after explosion by iron teeth. Nye, in 1647, recommended in addition measuring the penetration of pistol balls into clay, and the ranges of projectiles fired from a small mortar. By 1686, the French had adopted the *mortier éprouvette*, and in 1697 Saint Remy invented his pistol *éprouvette*, but it was not till 1742 that gunnery was placed upon a strictly scientific basis by the invention—described in General H. Müller's "Entwicklung der Feldartillerie" (Berlin, 1893), as "epoch-making"—of the ballistic pendulum. This invention, which Benjamin Robins for the first time gave to the world in his "New Principles of Gunnery" made possible the measurement with considerable accuracy, of the muzzle-velocity of projectiles.

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1698, 24th June. Sir Polycarpus Wharton's lease expired and was not renewed. He got into debt and was imprisoned. (Wharton, *loc. cit.*)

LIST OF GUNPOWDER MAKERS UP TO 1800

1457 John Judd in the Tower of London.
1512 Th. Hart in Porchester Castle.
1514 (? The King) in Bishopsgate Without in London.
1515 Hans Wolf, a foreigner, one of the King's gunpowder makers in the Tower.
1531 Thomas a Lee, one of the King's gunners, makes gunpowder.
1535 Thomas a Lee in Rotherhithe (see 1563, 23rd June, in chronology).
1540 Charles Wolman (also mentioned in 1552).
1541 Mill in Edinburgh Castle worked by "some workmen."
1555 Henry Reve on the "Crenge" in Rotherhithe.
1561 (*circa*) George Evelyn at Long Ditton.
(? Francis a Lee) at Leigh Place, near Godstone.
(? At Faversham.)
John Tomworth at Waltham.
Note.—Francis a Lee, Thomas a Lee's son, is variously mentioned later on as Lea, Lee, and Leigh.
1562 Bryan Hogge (his successor in 1589 was George Hogge) and Robert Thomas had, together with Francis a Lee, erected 5 mills.
1576 John Bovyat of London (see also 1581 and 1595).
1580 Sebastian Orlandini and John Smithe have a mill at Ratcliffe.
1588 George Evelyn (of Wotton, Surrey), Richard Hills (? Hill), and John Evelyn.
1589 George Constable, licensed for York, Nottingham, etc.
Hill, Constable, and John Grange enter into partnership, and put George Hogge on an annuity.

1599 John Evelyn, Richard Hardinge, Robert Evelyn, John Wrenham, and Symeon Turner are in partnership.

1607 Earl of Worcester; he relinquishes his patent in 1620.

1615 Christopher Newkirk (a Polish surgeon) knows how to make "still" powder.

1617 Richard Fisher of the Inner Temple, deputy of the Earl of Worcester.

1020 Manufacture taken over by the King, but John Evelyn appointed the sole maker.

John Baber (see also 1631).

1623 John Reynolds, master gunner of England and proof master for gunpowder.

1624 John Evelyn, the younger, Godstone, Surrey.

1625 East India Company outside Windsor Forest.

John Corseley, powder-maker to the City of Bristol.

Former powder makers in Bedford mentioned.

1626 East India Company licensed in Surrey, Kent and Sussex.

(? Thomas) Russell.

1627 Michael Waring in (?).

Bristol, Dorsetshire, and Battle powder makers to be suppressed.

1628 Robert King at Stockwell, near Chester.

1629 John Giffard in Devonshire, Thomas Guy made it without licence.

1631 Collins mentioned as the "workman" of the East India Company.

John Coslett and William Baber of Bristol.

1634 Sir John Heydon offers to make gunpowder.

Sir Philiberto Vernatti and John Battalion in Yardley, co. Herts.

Walter Parker, Stockwood, Dorset (since 1588 ?).

1635 Edward Collins, Chilworth.

Powder factories mentioned in Taunton.

1635 Sir Arthur Mainwaring and Andrew Pitcairn have 3 mills. (Place not stated.)

1636 Samuel Cordwell and George Collins, gunpowder makers of the King.

Robert Davies makes gunpowder in Thames Street, London; made it formerly in Whitechapel, where "he had his house blown up."

1640 Parker, near Bristol.

1643 Samuel Cordwell, works near Guildford.

1654 Sir Edward Randall succeeds Cordwell.

1660 General Daniel O'Neale (in Wotton ?).

1661 William Baber, Oxford.

1663 John Middleton, in Dublin.

1666 John Lord Berkeley and others. (Place not stated.)

1677 Sir Polycarpus Wharton at Chilworth.

1700 (about) Smith in Hounslow, successors were Hill, Isaac Butts, and Harvey and Grueber.

1719 Gruebarr of Ospringe, at Devington, near Faversham (in 1820 Harvey and Gruebarr at Hounslow dissolved partnership).

1728 Thomas Brock, fireworks maker.

1732 Pike and Edsall, Dartford.

1735 John Walton at Waltham.

1750 (?) at Hastings.

1751 (?) at Malden, Surrey.

1760 Faversham Works sold to Government.

1770 (?) at Brede, Sussex.

Bouchier Walton at Waltham.

1772 (?) at Battle, Crowhurst, Seddlescomb in Sussex.

1778 Dartford sold to Frederick Pigou and Miles Peter Andrews.

1780 (about) Merricks and Christie, Gorebridge, near Roslin.

1787 Government bought Waltham from John Walton.

1790 John Merricks, Roslin.

1794 Royal factory erected at Ballincollig in Ireland.

1838. Major-General James P. Cockburn.
1847. General Richard Hardinge, K.B.
1852. General Sir William Cator, K.C.B.
1852. Colonel John A. Wilson.

Superintendents

1855. Major-General Edward M. Boxer, F.R.S.
1870. Colonel Thomas W. Milward, C.B.
1875. Lieut.-Col. George H. J. A. Fraser.
1880. Colonel Francis Lyon:
1885. Colonel William R. Barlow.
1892. Colonel Edmond Bainbridge, C.B.
1899. Major James S. Douglas.
1902. Colonel Sir Hilaro W. Barlow, Bart.

THE ROYAL GUNPOWDER FACTORY, WALTHAM ABBEY

By Col. Sir Frederic L. Nathan, R.A.

THE earliest known record relating to the Waltham Abbey Powder-mill bears date 2nd March, 1560-1. It is of interest as showing that, even thus early, the factory was of considerable extent, and was engaged in producing gunpowder for the English Government. The substance of this record, given below, is extracted from the Essex volume No. 2 of "The Victoria History of the Counties of England." The historical details of the Waltham Abbey Gunpowder Factory which follow, are taken from the same source. On the date mentioned above, viz., 2nd March, 1561, one Marco Antonio Erizzo,

an Italian, writes[1] to John Thomworth (or Tamworth) at Waltham Abbey in reference to a tender he had made[2] to supply the Government with material for making powder. Thomworth was the executor of the widow of Sir Anthony Denny (who had died in 1549) and was probably the owner or manager of the powder-mill. The tender in question was referred for consideration to William Bromfield, Master of the Ordnance, who advised[3] that Neapolitan saltpetre at £3 10*s.* per cwt. was 10*s.* per cwt. too dear, and that the offer of 2,000 cwt. of Italian brimstone should be "respyted," as there were "in store at this present 120,000 c. weight, whiche wyll make foure hundrythe lasts of corne powder and wyll not be wrought yet into powder this fowre yeres." Ultimately, large quantities of powder-making materials were purchased from Erizzo, to the value of £6,000, including Italian brimstone at 18*s.* per cwt. and Neapolitan saltpetre at £3 5*s.* per cwt.; all to be delivered in England.[4] From that date, at any rate (and, doubtless, even earlier), the manufacture of gunpowder on a large scale has been carried on continuously at Waltham Abbey.

In his notice of the manufactures of Essex, Fuller, who became perpetual curate of Waltham Abbey about 1648, says that "More [gunpowder] is made by mills of late erected on the River Ley, betwixt Waltham and London, than in all England besides. . . . It is questionable whether the making of gunpowder be more profitable or more dangerous; the mills in my parish having been *five* times blown up within *seven* years, but (blessed be God!) without the loss of any one man's life."[5]

The first deaths from an explosion at the powder-mills are recorded in the register of burials of the parish of Waltham Holy Cross, under date October, 1665: "Tho. Gutridg, killed with a powder mill, ye 4 day: Edward Simons, carpenter, so killed, ye 5 day."

[1] S. P. Foreign, Elizabeth, xxiv, 1.
[2] S. P. Dom. Elizabeth, xvi, 33-4.
[3] S. P. Dom. Elizabeth, xvi, 35.
[4] S. P. Dom. Elizabeth, xvi, 36-7.
[5] "Worthies of England" (1662), pp. 318-19.

Farmer, in his "History of Waltham," gives a view of the factory as it was in 1735.[1] From this view, it appears that there were some twenty buildings as named thereon. Of the factory, Farmer says: "Near the Town on one of these rivers [*i.e.*, on one of the branches of the Lee] are curious Gunpowder Mills, which supply the nation with great quantities of gunpowder, being esteemed the largest and completest works in Great Britain, and are now the property of Mr. John Walton, a gentleman of known honour and integrity."

This John Walton was a relative of Izaak Walton, the angler.

In 1770 an Essex historian wrote of the factory as "several curious gunpowder mills, upon a new construction, worked by water, (the old ones having been worked by horses). They are reckoned the most complete in England, and will make near one hundred barrels weekly for Government service, each barrel containing one hundred weight. They are now the property of Bouchier Walton, Esquire."

Horse power would appear, however, to have been introduced as early as 1739, and was used to some extent to a considerably later period than 1770.

In 1787 the factory was acquired by the Government from another member of the family, a later John Walton. A pillar sundial, which belonged to this John Walton, and has his name engraved on it, still stands in front of the offices of the factory. The surrounding lands were not finally purchased till 1795. Upon becoming Crown property, the factory was enlarged by the Board of Ordnance, under whose management it fell. Some fourteen or fifteen of the old hands were retained, and workmen were brought also from the King's Powder-Mill at Faversham, both the Faversham and Waltham Abbey factories being worked under the superintendence of Major (afterwards Sir William) Congreve, Deputy-Controller of the Royal Laboratory at Woolwich. Forty-six hands were employed in October, 1787, at which date stone runners and beds, such as are still occasionally employed, were in use for the process of "incorporating" (*i.e.*, mixing).

[1] Reproduced on p. 161.

In 1791 the factory records speak of double horse-mills being in use; and in 1795, powder appears to have been sent regularly from Waltham Abbey to Purfleet, for proof. Sometimes it went overland in ammunition wagons, at other times by water in barges.

Explosions seem to have occasionally occurred at this period; but, as a rule, they did no serious injury. In 1801, however, a horse "corning-house" exploded, killing nine men and four horses. In consequence of this explosion, a committee of the Royal Society visited the works to examine and report on the possibility of danger arising from electrical excitation, caused by walking or rolling barrels on the leather-covered floors, or by the use of silk-covered "dusting reels," in which the fine dust is removed from the grain powder. The committee reported, however, that there could be no danger from such causes.

The introduction into the manufacture of gunpowder of charcoal burnt in retorts or "cylinders" instead of in "pits," occurred about this time. In 1804 and for some years afterwards, Government cylinder works, in connection with the Waltham Abbey factory, were maintained at Fisher Street and at Fernhurst, in Sussex. In the same year occurs the first mention of iron runners and beds for incorporating mills. The annual yield of the factory at this period was about 20,000 barrels.

In 1805 the Board of Ordnance purchased the Cheshunt corn-mill, and in 1809 the Waltham Abbey corn-mill, for the sake of their water-power rights.

In 1811, in order to show that the manufacture of gunpowder could be carried on more economically at the Royal Gunpowder Factories at Waltham Abbey and Faversham than by private merchants, General (afterwards Sir William) Congreve addressed a statement on the subject, dated 20th April, 1811, to the Master-General of the Ordnance. This statement showed that the profit, between 1st January, 1789, and 31st August, 1810, on 407,408 barrels of gunpowder of 100 lb. each, made at Waltham Abbey and Faversham, amounted to

£288,357 6s. 0½d.; and that the profit on "regenerating" 127,419½ barrels, between 1st January, 1790, and 31st August, 1810, was £53,091 11s. 3d., or a total profit of £341,488 18s. 3¾d. The same statement gives the whole amount expended by the Government on the original purchase, and on new erections, repairs, and improvements, up to 31st December, 1799, as £45,683 2s. 7½d.

On the morning of 27th November, 1811, there was another serious explosion, a press-house and a corning-house being blown up and eight men killed. After this Sir William Congreve substituted Bramah hydraulic presses for the old screw-presses used previously for giving the requisite density to the gunpowder. On October, 1814, it was ordered that, for working the machinery, water-power was to be substituted entirely for horse-power. At this time, in all probability, horse-power was finally disused. In 1810, according to Winters ("Centenary Memorial," pp. 67 and 78), there were in use nine water-mills and seven horse-mills; and in 1813 (when the war was at its height), twenty-four water-mills and nine horse-mills. In 1816 the old corning-frame was replaced by a new granulating machine, patented by Sir William Congreve, Patent No. 3937 of 1815 (3rd July). It was erected on that portion of the factory known as the Lower Island.

During the war with France, very large quantities of gunpowder were produced at Waltham Abbey, the figures for the later years being as follows:

Years.	No. of Barrels.
1809	20,050
1810	20,688
1811	21,252
1812	21,000
1813	25,060
1814	10,161
1815	15,790

On the conclusion of peace, the output was much reduced. In 1816 it amounted to about 4,000 barrels only; in 1819 it had fallen to about 1,000 barrels; and in some succeeding years, it was even less. In addition, however, large quantities of old powder were "regenerated" each year at this period. In 1822 the establishment was fixed at thirty-four persons. In 1813, during the war, it had exceeded 250 hands, and the wages paid to them had amounted to £17,212 (*see* Winters, "Centenary Memorial," pp. 75-8).

In 1832, the Royal Factory at Faversham was sold, and shortly afterwards the Royal Factory at Ballincollig, in Ireland, was disposed of also. Waltham Abbey thus became the sole royal gunpowder factory, and has remained so to the present day.

From April, 1858, to the end of March, 1859, the factory produced 10,683 barrels of gunpowder and was capable of storing 5,000 tons of saltpetre and sulphur. The value of the buildings, land and water rights was estimated at £230,000.

Colonel Askwith was the first Superintendent independent of the Royal Laboratory. He was appointed from the 18th August, 1855.

In 1858, Sir W. Snow Harris, F.R.S., after an inspection of the factory, drew up a report for a system of lightning conductors for all the houses in it. They were subsequently installed.

In 1870 the factory contained thirty-two pairs of incorporating mills, some driven by water and some by steam. These could incorporate annually materials for about 27,580 barrels of large grain, or 13,690 barrels of fine grain gunpowder. The number of men employed was about one hundred and fifty. All the processes preparatory to the actual manufacture of the powder were carried on in the factory, in order to ensure the absolute purity of the finished article. These processes included the refining of sulphur and saltpetre, and the burning of charcoal in cylinders.

For many centuries black gunpowder was the only explosive. Nothing else was made at the Waltham Abbey Factory until 1872,

when the production of guncotton was commenced on a manufacturing scale.

The original guncotton factory consisted mainly of old buildings, which had formed part of the saltpetre refinery, and abutted on the principal street of the town. It was capable of turning out about two hundred and fifty tons of guncotton per annum. In 1885 one hundred acres of land, known as Quinton Hill, were purchased by the Government, and a new guncotton factory, which started work in 1890, was erected there.

The kind of gunpowder known as "brown" or "cocoa" powder, was introduced from Germany in 1883, and a number of new buildings were erected in the old part of the factory for its production, which was commenced in 1885.

Smokeless powders for military purposes were first produced in France, in 1886. In 1890 the Explosives Committee recommended a smokeless powder, to which the name of "Cordite" was given, and its manufacture was commenced at Waltham Abbey in 1891. For its production a nitro-glycerine factory was put up on Quinton Hill, where the necessary buildings for making cordite were also erected. In 1898 a second nitro-glycerine factory in the old portion of the factory, started work, and the majority of the houses formerly used for the manufacture of gunpowder were adapted for the manufacture of cordite in consequence of the larger output. The introduction of modified cordite entailed considerable additions to the factory, and 94½ acres were acquired for the erection of the necessary buildings.

The factory at the present time covers 411½ acres, and comprises about 300 separate buildings. It is under the superintendence of Colonel Sir Frederic L. Nathan.

Gunpowder, fine grain powder for fuses and for the priming of cordite cartridges, picric powder, nitric acid, nitro-glycerine, guncotton for torpedoes, mines, etc., as well as for cordite, and cordite, are manufactured at Waltham Abbey. In addition to the above the waste acids resulting from the manufacture of nitro-glycerine and guncotton are

recovered, as is also a large proportion of the acetone used in the manufacture of cordite. The saltpetre and sulphur used in gunpowder are bought in the rough state and are refined in the factory, and the charcoal is made from wood mostly grown on the spot.

The four main departments of the Royal Gunpowder Factory are: Gunpowder, Nitro-glycerine, Guncotton, and Cordite. There are also a Machinery Department and a Central Laboratory.

Electrical power is almost universally employed, supplied from a central generating station in which are three 200 K.W. generators, and three smaller ones. The factory is electrically lighted from the same source. Alongside the Power House is a Main Boiler House, containing fifteen 30 feet by 8 feet 100 lb. pressure Lancashire boilers. These boilers supply steam for the boiling of guncotton as well as for the generators. For heating purposes there are three other smaller boiler houses in different parts of the factory.

All raw materials, as well as the finished explosives, are tested and examined in the Central Laboratory, and in the laboratories attached to the Nitro-glycerine and Guncotton Departments, under the Chemists-in-Charge. Research work of a varied nature is also carried out at the Central Laboratory.

The whole of the work in connection with the manufacture of explosives is carried out under the strictest supervision, and every possible care is taken that all finished products issued from the factory shall be of the greatest purity, stability, and uniformity, as these are factors of paramount importance to the Services. Every precaution tending to reduce the risk of accident during manufacture is also most stringently enforced.

The Company's "Permitted" Explosives comprise:

Rippite	Dragonite	Excellite
Curtisite	Kolax	Cliffite
Bobbinite		

all of which are the invention and sole property of the Company. "Bobbinite," for which there is a great demand both in this country and abroad, is the only low explosive of the gunpowder type which has succeeded in retaining its place on the "Permitted List" for use in gaseous and fiery coal-mines.

The "Ironclad" Incandescent Gas Mantle, with a metal top in place of the usual asbestos loop, is also a speciality of this firm.

The firm has obtained numerous distinctions, amongst these are as early medals at international exhibitions as: Philadelphia, 1876, and Paris, 1878.

Messrs. Curtis's and Harvey, Limited, were constituted a public company in 1898, and incorporated the following firms:

Curtis's and Harvey, with factories at Hounslow, Tonbridge, Glyn Neath, Kames, Glenlean.

John Hall and Son, Ltd., Faversham.

Pigou, Wilks and Laurence, Ltd., Dartford.

Ballincollig Royal Gunpowder Works, Ltd., near Cork.

Hay Merricks and Co. Ltd., Roslin, near Edinburgh.

The Kennall Vale Gunpowder Co., Perranwell Station, Cornwall.

The East Cornwall Gunpowder Co., Liskeard, Cornwall.

The Midlothian Gunpowder Co., Ltd., West Calder.

The War and Sporting Smokeless Powder Co., Ltd., Trimley, near Ipswich.

Hounslow.—It is difficult to say when Hounslow, the original factory of Messrs. Curtis's and Harvey, on the estate of the Duke of Northumberland, was first devoted to the manufacture of Gunpowder. There is no doubt, however, that it possesses a very considerable antiquity, and at all events in the early part of the eighteenth century

explosives of the gunpowder type which have successfully passed the Woolwich tests for the "Permitted List." The earlier examples of the "Elephant" cartridge, "Bull-dog" and "Special Bull-dog," developed into the present coal-getting explosive "Bobbinite," which maintains its position on the "Permitted List," and continues to be very popular.

Dartford.—The town of Dartford has long been connected with gunpowder making. Hasted's "History of Kent" (1778) mentions "Mr. Edsall's powder-mills,"[1] and early in the nineteenth century the firm of Pigou and Wilks were in possession of the factory, and achieved a very high reputation for their military and sporting powders. They subsequently amalgamated with the firm of Charles Laurence and Son, of Battle, and ultimately became a limited company under the style of Pigou, Wilks and Laurence, Limited.

About 1890 a guncotton factory was erected on land adjacent to the old black-powder factory, and a nitrocellulose powder on the "Troisdorf" system manufactured.

In 1898 the company was incorporated with Messrs. Curtis's and Harvey, Limited.

The black-powder factory has now been given up, and has reverted to the Pigou family, who are owners of the freehold. The guncotton factory is, however, still retained and worked by Messrs. Curtis's and Harvey, who have also installed a factory for the manufacture of incandescent gas mantles.

Ballincollig.—The works at Ballincollig were established as a royal factory in 1794 on land adjacent to the Cavalry Barracks, and with very excellent water-power provided by the River Lea. It continued to be worked for Government purposes until 1834, when it was sold to Sir Thomas Tobin, of Liverpool, and subsequently took the style of the "Ballincollig Royal Powder Works, Limited." As such

[1] The factory was instituted in the old Spilman paper mills in 1732 by Pike and Edsall. In 1778 Edsall became bankrupt, and the factory was sold to Mr. Pigou.

it did a large business in Ireland and in export powder shipped from Liverpool for the African market.

In 1898 it passed into the possession of Messrs. Curtis's and Harvey.

For the last few years it has been standing idle.

Roslin.—These works were established in 1790 by Mr. John Merricks, who had previously, in association with a Mr. Christie, owned mills at Gorebridge, a few miles off. Owing to frequent mishaps at Gorebridge, the mills were closed, and Mr. Merricks founded with Mr. Hay the new firm of Hay, Merricks and Company at Roslin.

The factory is half driven by water and half by steam, and is very picturesquely situated on the river Esk, in close proximity to the celebrated Roslin Chapel. It did a large business in sporting and blasting powders both for home and abroad, and towards the end of the last century obtained a considerable share of the Government contracts which had hitherto been practically monopolized by the three firms of Curtis's, Hall, and Pigou.

The factory passed into the hands of Curtis's and Harvey, Limited, in 1898, and does a considerable business in black powder and "Bobbinite" (the credit for the invention of which belongs largely to the late manager, Mr. A. F. Hargreaves, F.R.S.E.

Extensive additions have been made to the factory in connection with the manufacture of "Cheddite."

Midlothian.—This factory, situated some four miles from West Calder, was established in 1889, for the purpose of supplying the blasting powder used in the district. In 1895 a saltpetre factory was added, for the cheaper production of that essential ingredient of black powder.

The factory is the most modern black-powder works in the country, being the only one established since the passing of the Explosives Act in 1875.

It was incorporated with Curtis's and Harvey, Limited, in 1898, and continues to do a large local trade in blasting powder.

Storehouses on Horse Mill Island (originally a stable) must be considered a crippled building owing to its having been injudiciously loaded with sulphur.

The Committee recommended that:

1. All mills newly erected should be placed angularly and not opposite to each other on their respective banks of the Mill Head.
2. Water wheels and shafts should be made of cast iron instead of wood.
3. Powder should be glazed in barrels instead of reels.
4. Self-registering thermometers should be introduced into the drying room to indicate to the Superintendent on each inspection the greatest and lowest degree of heat that has been applied to dry the powder.
5. Steam stoves rather than Gloner stoves should be approved.
6. As the duties of the several persons employed in responsible situations have never been defined on any general principle of subordination or mutual co-operation, and at this time the chief of each division or branch of the manufactory regulates his practice on partial instructions or established usage and the Service has not the benefit of perfect unit and accord, some person under the title of Superintendent and living on the spot should have such a general control over all the working departments of the Manufactory as to be able to continue and direct their efforts at all times and under all circumstances to the advancement of the public interests, provided each Master Worker or Refiner by means of instructions from the Board specifying his responsibility and charge over his particular department, be protected from all possibility of wanton innovation or vexatious interference on the part of the Superintendent.

In 1843 a further terrible explosion in two corning houses, a press house and a reel house shook the factory and caused the loss of seven lives. It originated in a building where one of the old corning machines with shaking frames was at work. No machine of this description has been used at Waltham since, and soon after the accident, Professor Faraday and Colonel Cockburn, Director of the Royal Laboratory, visited the factory to report on various matters connected with the safety of the buildings. Twelve years afterwards the factory was transferred to the War Department.

Faversham, Ballingcollig and Waltham Abbey were under the control of an artillery officer styled in 1811 the *Inspector of the Manufactory*.

As has already been stated, the connection of the Ordnance with the small arms trade dates from June 1631. This trade, originally carried out in London, moved to Birmingham in the eighteenth century or rather then commenced there *de novo*. As a result, the Office of Ordnance established a proof-house in that town to facilitate supplies. The business of the small arms department at the Tower was carried on by civilians deputed by the Surveyor-General and the Principal Storekeeper, assisted as necessary by the master furbisher. They received their orders, either directly from the Master-General and the Board, or through the Principal Storekeeper. Such means of supply were totally inadequate for the country's requirements and, therefore, by the end of the eighteenth century armed forces of the Crown depended for their complement of arms primarily upon the trade. When such a source proved insufficient, recourse