On Her Majesty's Service

An American Powder Maker in Great Britain – Lammot du Pont's Journal, 1858

Dr. Norman B. Wilkinson

Trans. Newcomen Soc.

47 Ps. 85-96

Public Record Office, London, Reference No. SUPPLY 5/274

Original Correspondence Letters Received - Superintendent Vol. 8, page 55

Copy of a letter, dated 28th April, 1858, from the War Office, London, to Superintendent, Royal Gunpowder Factory.

War Office
28th April 1858

Sir,

Permission having been given to Mr. du Pont, of the United States, to visit the Royal Gunpowder Factory; I am directed by Secretary Major General Peel to request that you will afford him such assistance as he may require, consistently with the rules imposed in the cases of Foreigners visiting Government Establishments -

I am

Sir

Your obedient Servant

H.R. Drewry

The Superintendent

Royal Gunpowder Factory

Waltham Abbey.

War Office
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Your obedient Servant

H. K. Storey

Superintendent
Gunpowder Factory
Waltham Abbey

L.H. 114 S.
Tel. No.—Waltham Cross 23688

From MINISTRY OF AVIATION,
DIRECTOR,
EXPLOSIVES RESEARCH AND
DEVELOPMENT ESTAB.,
WALTHAM ABBEY,
ESSEX.

Our Ref. ENQ. 1378

MEMORANDUM

10th June 1963

To The Secretary
Public Record Office,
Chancery Lane, W.C.2

Your Ref.

Subject Photocopy — Supply 5/274

It would be appreciated if you would please arrange, as soon as possible, one positive paper photocopy of page 55 (letter re Mr. du Pont's visit to Royal Gunpowder Factory) of the above reference.

It is understood that Supply 5/274 will have been called in from Ashridge following my telephone request earlier to-day.

Malcolm McLaren
for Director, E.R.D.E.

L.H. 114 S.
Tel. No.—Waltham Cross 23688

From MINISTRY OF AVIATION,
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EXPLOSIVES RESEARCH AND
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To The Secretary
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Malcolm McLaren
for Director, E.R.D.E.

L.H. 114 S.
Tel. No.—Waltham Cross 23688

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Our Ref. ENQ 1378

MEMORANDUM

10th June 1963

To The Secretary
Public Record Office
Chancery Lane W.C.2

Your Ref.

Subject Photocopy — Suffly 5/274

It would be appreciated if you would please arrange as soon as possible one positive paper photocopy of page 5 5 (letter re Mr. du Pont's visit to Royal Gunpowder Factory) of the above reference.

It is understood that Suffly 5/274 will have been called in from Ashridge following my telephone request earlier to-day.

Malcolm McLaren
for Director, E.R.D.E.

PRO. 6.6.1963
Supply 5/274 Page 55

RGPF stamp
Rec'd Apr. 29 1858

War Office
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Public Record Office Reference Supply 5/274
6 pages 55

Copy of a letter from the War Office, London to the Supt. R.G.P.F. dated 28.4.1858

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An American Powdermaker in Great Britain: Lammot du Pont's Journal, 1858

by

Dr. Norman B. Wilkinson

Read at the Science Museum, London, S.W.7, on 9th April, 1975

Lammot du Pont (1831–1884) was a third generation member of the Du Pont Company, a family enterprise which by the 1850s had become the principal manufacturer of black powder in the United States. After graduating from the University of Pennsylvania with a major in chemistry he had worked in the family mills on Brandywine Creek near Wilmington, Delaware, for eight years before journeying to Great Britain and the Continent in 1858. His earlier working experience had been refining saltpetre and making charcoal, which, with sulphur, were the ingredients of black powder, the only explosive then known. But knowledge of the complete process of black powder manufacture was soon learned by Lammot under the tutelage of his father, Alfred Victor, and his uncles Alexis I. and Henry du Pont.

His career in the powder business began at a propitious time for it coincided with increasing demands for black powder in railway construction, coal mining, iron and copper mining, and by hunters, traders and migrants who made up the westward movement surging across the breadth of America. Powder was supplied to the U.S. Army and its outposts in Indian country: shipments were made to Central and South America, and manufacturers in the neutral U.S. had sold to both belligerents during the Crimean War (1853–1856). Du Pont Company sales figures reflected this flourishing state of the business, rising from $258,586 in 1850 to $694,814 in 1855, the highest they were to reach until rumblings began to be heard of civil war in 1860.[1]

For several decades a major effort of American powder-makers had been to find a cheap, effective substitue for Indian saltpetre, potassium nitrate (KNO_3), available only through British brokers who controlled the trade. Lammot du Pont worked on this and in 1857 perfected and patented a process using South American saltpetre, sodium nitrate ($NaNO_3$), which cost about half the price of Indian saltpetre, and the supply of which was not as readily subject to the vagaries of British foreign policy which could shut off shipments to the U.S. in times of crisis.[2]

The new soda or 'B' powder, however, was too hygroscopic, moisture-absorbing, to be used for hunting, sporting or military purposes. But it was effective as a cheap blasting powder which lowered costs in the burgeoning extractive and excavating industries. When put on the market its quick acceptance gave the Du Pont firm a decided advantage over its competitors.

Fig. 1. Lammot du Pont (1831–84). From a daguerrotype, c1860.
Courtesy of Eleutherian Mills Historical Library.

The first mention of Lammot visiting powder mills in Europe came a few months after he had been granted his patent. Whether his uncle, Henry du Pont, now head of the firm, considered it a bonus or recognition for his achievement is not known, but a solicitous aunt who saw him almost daily thought he needed a change[3]:

> His life is a very arduous one and he is, I think, overtasked. He superintends the department of saltpeter refining and burning the charcoal. . . . He is 26 years of age, a most exemplary young man. We all love him dearly.

Preparations began with the securing of letters of introduction which might open doors customarily closed to outsiders. Some were obtained from officers in the U.S. Ordnance Bureau and others from several business houses with European connections. James Bidermann, an uncle who had made a prolonged stay in Europe in the years 1837–1839, gave him letters and copies of memoranda and technical notes made when he had visited the Waltham Abbey Works. Lammot solicited a letter from President James Buchanan, noting that he hoped to gather information which could be useful to the United States in regard to its supplies of gunpowder. Buchanan responded with instructions to the U.S. Ministers in Paris, Berlin and St. Petersburg requesting their good offices to facilitate du Pont's access to the government mills in France, Prussia and Russia.[4]

Passage was booked on the Collins Line steamer *Adriatic*, sailing 24 August, 1857, but tragedy intervened when his younger uncle, Alexis Irenée, and five workmen were killed in an explosion two days before his departure. The trip was postponed indefinitely, for Lammot was the person best qualified to assume his uncle's responsibilities.

In November, an English powder manufacturer named Henry E. Drayson, a partner in the Maresfield Powder Company in Sussex, visited the Brandywine mills. He described some of the principal features – the machinery and methods – of his own and other English mills, including the government mills at Waltham Abbey where his father had been superintendent for forty years. The tour of the Du Pont mills which followed this conversation ended with Drayson declaring to Lammot and Henry du Pont that 'there was no use in any of us to go to Europe as we *could not learn anything*'. Lammot was sceptical of this implied compliment, noting in his memorandum of Drayson's visit – 'This was a piece of Blarney which might be interpreted into stupidity'.[5] Young Du Pont had a sense of history. Europeans had been making black powder for six hundred years, Americans for scarcely a century: despite the technological 'leap forward' America had made in recent decades Lammot was well aware that long experience could not be overlooked as a teacher. No doubt, his determination to make the trip to Europe was reinforced by a dictum expressed years earlier by his father: 'In an establishment like this it is essential that we keep ourselves informed of whatever is new in our line'.[6]

On loose, legal size blue sheets of paper Lammot made his first journal entry by noting his departure as one of thirty-eight passengers sailing on the Cunard liner *Arabia* leaving New York on 17 February, 1858. Except when occasional bouts of *mal-de-mer* prevented it he made a daily record of the things which would interest a curious, gregarious person on his first Atlantic crossing, e.g., heights of waves and depths of troughs, distances travelled daily, hailing passing ships, icebergs seen and sea creatures sighted; latitude and longtitude, fellow passengers and their idiosyncrasies, gambling (moderately) and playing chess (expertly); chatting with the captain over a good cigar, and nearly causing him to choke when Lammot casually remarked that his luggage contained four pounds of gunpowder! What words of castigation followed Lammot did not record, but the captain immediately ordered the dangerous stuff stowed in the ship's magazine.

After ten days at sea the *Arabia* docked in the early evening at Liverpool, on first impression a dirty and disagreeable city whose buildings, he noted, looked as though they had been built to last a thousand years. After a night at the Adelphi Hotel he presented himself the next day at the office of Brown, Shipley & Co., a firm of merchants with Wilmington connections, where a letter of credit had been deposited against which he could draw funds as needed.

The Elterwater Powder Company near Ambleside, Westmorland, was first on his itinerary. After an impatient wait of two days for an answer to his written request to visit the plant he was refused admission, not because the proprietors 'had any jealousy against us', Lammot wrote in disgust, but because it was too dangerous! To one born a few hundred yards from powder mills, who had lived through several devastating explosions and had worked 'in the powder' for eight years, this seemed a flimsy alibi for the purpose of keeping an outsider from learning any manufacturing secrets the Elterwater people might have.

Leaving Liverpool he took the train to London where he made Morley's Hotel his headquarters. Awaiting him here was a letter from his mother written four days after he had sailed. Despite his maturity (he was nearly twenty-seven and unmarried) she thought he needed to be reminded of several cultural and social amenities that would mark him a gentleman, acceptable to those upon whom he would be calling:

> Try, my son, not to make mistakes in spelling, or in grammar when you converse. *Those two*, correctly done, show to others that you are well bred and born. If you go to a *regular dinner* party you must wear white gloves.

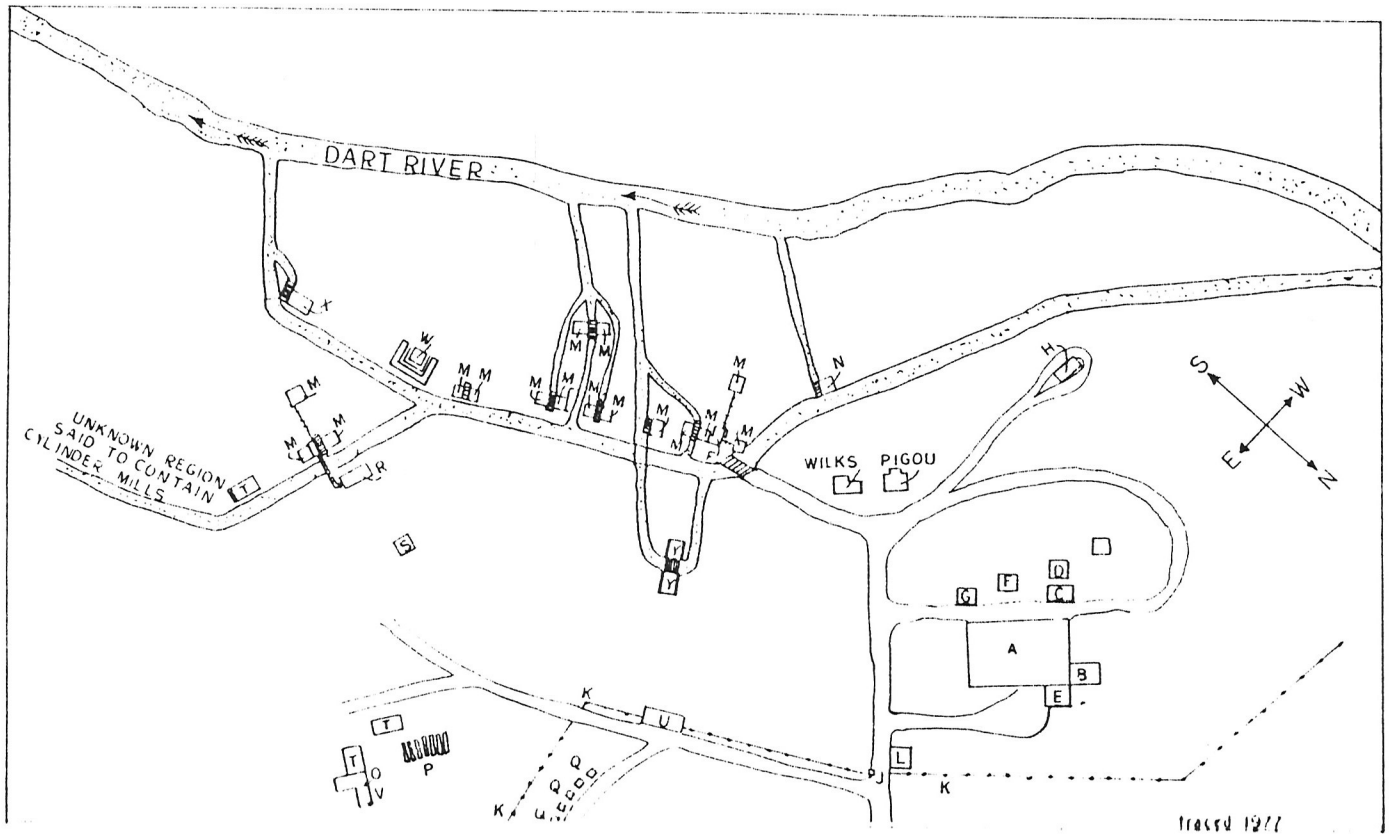
And as a preparatory caution given to visitors not familiar with British weather – she said, 'I hope you get an umbrella and gum shoes, articles you must have in England's wet clime'.[8]

With these admonitions fresh in mind and armed with a letter of introduction, on 6 March Lammot rode the seventeen miles to Dartford in Kent to visit Pigou and Wilks, a principal supplier of powder during the Crimean War and one of England's oldest powdermaking firms, dating back to the early 1600s. He was given a friendly reception by Mr Wilks, who regaled him for an hour on the history of the firm and then took him on a tour of the plant. The prime source of power was the River Darent, a smallish stream with a fall of 7 ft. 6 ins., about one-third of the fall of Brandywine Creek at the Du Pont mills. To supplement the water power which would be ineffective in time of drought or winter ice were four steam engines to turn the iron breast water wheels in the incorporating mills. Possibly safety considerations had kept the Du Pont Company from early adoption of steam engines in its plant; only one, a horizontal high pressure engine, was in operation in the mid-1850s, and this was in the refinery where the work done was relatively safe.

The refinery operations were of particular concern to the young American. He noted the absence of a laboratory for the analysis of crude and purified saltpetre. No analysis was made of the discarded salts, mostly muriate of potash which was sold as fertilizer. He observed that Mr. Wilks did not understand chemistry and no mention was made of a company chemist who would perform such tasks. The records of the Du Pont firm from its founding are replete with insistence upon purchasing both saltpetre and sulphur that met established criteria and that were then refined and sublimated in ways to produce raw materials of the highest quality. There had long been a laboratory in its refinery and Lammot had a small private laboratory-workshop adjacent to his home. The contrast in the practices of quality control at this stage could not have been lost upon him.

The Pigou and Wilks refinery was a one-storey structure 60 by 80 ft., having a slate roof with lead gutters which caught rain water used for boiling the saltpetre in the refinery kettles. To expedite movement of materials a railway linked the refinery to a crude saltpetre warehouse on one side and on the other to a storehouse for the refined crystallized saltpetre. Railway wagons, really tubs on wheels with false bottoms and drain plugs, carried the crude saltpetre to the melting kettles, each of which was six feet across and three feet deep. After long hours of boiling, clarification with glue as a coagulant, and the skimming off of impurities, the hot liquid saltpetre was run into copper-lined wooden coolers 14 ft. long, 6 ft. wide and a foot deep from which excess liquor drained off as cooling occurred. Cooling and crystallization continued as the liquid saltpetre ran into two other sets of coolers, each a foot lower than the one above. As workmen stirred the cooling liquid, crystals formed which were raked on to the upward slanting sides of the coolers. When a quantity of crystals had accumulated they were once more placed in the wagons, covered with water and allowed to set for several hours, after which the water was drained off into catch basins set between the rails. This 'mother water' still contained some saltpetre which was recovered by being returned to the melting kettles to be put in with the next batch of crude saltpetre. Final drying of the crystals took place in large shallow copper pans in a steam-heated dry house. The finished product, Lammot noted, was coarser than Du Pont saltpetre, containing about 1¼ per cent moisture, and about one part foreign salts to 10,000 parts of pure saltpetre. He does not state directly whether the finished product could be considered *raffine en neige* – the French term for the finest quality saltpetre.

Only passing note was made of sulphur preparation, that it was done by the traditional method of sublimation and that Sicily was the source of the crude ore. Charcoal was made from English dogwood, willow and black alder. Instead of 'harvesting' each Spring branches two to four inches in diameter only, as was the Du Pont practice, the English firm cut down the entire tree, trunk and branches, a depletion of resources that struck Lammot as wasteful. The thicker pieces were run through a sawmill before the bark was peeled off and the cut and peeled wood was then stacked outdoors to dry in the air, each core being marked to show the date it was cut.



A – Refinery
B – Dry house to dry gunny bags and staves
C – Refinery to re-work refuse salts
D – Refinery to evaporate dirty water
F – Powder cart shed
G – Shed for wheelbarrows
H – Magazine
Pigou – Residence of Mr. Clarence Pigou
Wilks – Residence of Mr. Wilks
I – Charcoal roller pulverizing mill
JJ – Powder yard gates
KK – Powder yard fence
L – Gate tender's lodge
MM – Rolling mills
N – Sulphur pulverizing mill
O – Engine and boiler house
P – Cords of alder wood
Q – Cords of Willow and English dogwood
R – Charcoal 'coffee mill' pulverizer
S – Packing house
TT – Coal [charcoal burning] houses
U – Barn and stables
V – Circular sawmill
W – Press house
X – Granulating mill
Y – Glazing mill

Fig. 2. Sketch plan of the Powder Mills of Pigou & Wilks at Dartford. (Traced from Lammot du Pont's journal, he named the river in error.)

Charring was done in horizontal cast-iron cylinders three feet long and two and a half feet in diameter set above furnaces. The gases produced were piped back into the furnaces as supplementary fuel. Lammot makes no note of the other by-products of the charring process, tar and pyroligneous acid, the former used as caulking and for making creosote, and the latter sold to paint and chemical manufacturers and also used as a meat preservative. His firm had an active subsidiary business in these by-products. The finished charcoal was pulverized under edge runners, but a recent innovation made by Pigou and Wilks was a pulverizing machine that resembled a coffee mill.

The edge runner mills in which the three ingredients were incorporated together were constructed very differently than those with which Lammot was familiar. Three walls were of light frame, the fourth brick, and the roof was made of corrugated iron sheets ⅛ inch thick. The Brandywine mills had three heavy stone walls, each three to four feet thick, some with supporting buttresses and flash walls. The fourth side facing the stream was either open with a canvas drop, or of light frame, and the roof usually shingle or lightweight metal sheets loosely attached. When an explosion occurred the thick walls were designed to withstand the force of the blast and vent it through the open front and through the roof into the creek and the wooded shore opposite, theoretically preventing damage to mills adjacent to the one blown up. Sometimes it did, sometimes it did not, depending upon the force of the explosion. Lammot makes no observations as to the advantages or disadvantages of the two types of construction, the safety factors, the initial costs of erection, or the time and expense required in getting a shattered building back into operation.

Before entering one of the nineteen pairs of incorporating mills Lammot and his guide pulled rawhide slippers on over their shoes as a precaution against a shoe nail sparking powder dust on the floor. All the mills had overhead shafting transmitting power from the water wheels to a central shaft to which the edge runners were attached. Overhead shafting and gears had been standard in the older Du Pont mills, but after losing them in a number of explosions the shafting and gears had been placed beneath the floor of the mill where there was less likelihood of their being shattered by an explosion.

A novel safety device which caught Lammot's eye was a large porous water bag suspended above the edge runners and the ingredients tub. Water seeped from it along dangling strings and dripped on to the ingredients in the tub keeping them moist as they were being ground and incorporated together. It was absolutely essential that the material be kept moist for if it became dry and 'dusted' – throwing off a fine powder dust into the mill – the possibility of an explosion was considerable. In the Du Pont mills a workman shut off the power periodically, stopped the runners, and added water if the mixture felt dry or gave signs of 'dusting'.

Most of the Pigou mills had stone runners, each weighing 3½ to 4½ tons; the others had cast iron runners weighing about 3 tons each, about half the weight of the Du Pont edge runners. It was believed that the heavier runners made a more thorough or homogeneous incorporation of the ingredients. The length of time the mixture was under the runners also determined its quality, the best grade sporting powder being rolled up to ten hours or more, while common blasting powder was under the runners from one to three hours.

To give powder its required density the moist powder-cake was taken from the incorporating mill to the press mill where it was spread on wooden trays, 2 x 3 ft., stacked on top of one another in a vertical press box to a capacity of 800 pounds, and then pressure applied. This was done by turning a windlass which lowered a cap or platen on to the pile of trays, the pressure being increased until the layers of powder were squeezed to a thickness of about 1⅛ inches, giving it the appearance of a piece of slate. This 'presscake' was then run between zinc-toothed cutting rolls to break it into small pieces before going to the graining mill. Lammot noted that the press house was the only structure of the entire plant which was entirely surrounded by an earth embankment, indicating that it housed possibly the most hazardous operation of the entire process.

Graining or granulating the powder to the desired size was done in another mill where the presscake chips were fed into a hopper set above two pairs of horizontal zinc rolls, the upper pair placed at a 40° angle above the lower pair. The rolls, turning at 30 revolutions per minute – about one-sixth the speed of the Du Pont graining rolls – crushed the chips into granules which flowed on to slightly inclined vibrating copper sieves with mesh of the size of grain desired. The grained powder and powder dust fell through the sieves on to the floor and the oversized pieces slid off the sieves into a catch bin. The sized powder and dust were separated in a sifting bin, the dust and the over-sized

powder chips being returned to the incorporating mills to be re-worked with the next batch of powder. Lammot noted a safety device new to him in the form of a compound lever which automatically stopped the machine if an object too large or too hard for the rolls to crush jammed the runners.

Glazing the powder to dry it further, to round the grains and coat them with black lead, was done in revolving barrels in the same manner as in the Du Pont mills. Lammot sought Mr Wilks' opinion of the value of black lead, or plumbago, for coating the grains. Du Pont had been doing this only since the early 1850s, yet it was considered of dubious benefit by some powdermakers who thought it slowed down the rate of combustion. Mr. Wilks replied that quarrymen preferred it because it resisted dampness in the quarry holes into which it was loaded.

A final drying of the powder, either by sunlight on outdoor tables, or in a heated dry house is not mentioned by Lammot, nor does his sketch of the plant show either, which suggests that Pigou and Wilks considered the powder was sufficiently dry and ready for packing after being glazed. At the beginning of the tour Mr. Wilks had stated that average daily production amounted to 200 25-lb. kegs; Lammot guessed that 120 kegs might be more accurate. Du Pont production at this time averaged 800 kegs daily.

On leaving he was promised by Mr. Wilks that six pounds of the best quality sporting powder would be sent to the firm's London office for Lammot to pick up and take home. Lammot appreciated his host's generosity and his willingness to discuss and show him the plant's operations. He invited Mr. Wilks and other members of the firm to visit the Du Pont mills if they should ever come to the United States.

The visit to Pigou and Wilks has been described at length because Lammot's account of it is the most detailed and his sketch of the factory's general layout and some of the well-executed drawings of floor plans, machinery and other equipment are used to illustrate this paper. This initial visit may also serve to introduce the reader to the technology of black powder manufacture. Lammot's observations made at visits to other mills will focus upon aspects of processes and machinery that may have been new to him; those that differed from plant to plant; those which in his opinion were not as advanced as Du Pont's, and others that might be of benefit if adopted. He anticipated that his journal and drawings would serve as an aide-memoire for discussions with his Uncle Henry and other members of the firm when he returned home.

Next on his itinerary were the Roslin Mills of Hay, Merrick and Company, about six miles from Edinburgh. On the train to Scotland he fell into conversation with a machinist who recently had made six pairs of edge runners for installation at the Waltham Abbey Mills, the government mills Lammot was most anxious to inspect. The machinist promised to send him plans of some new incorporating mills soon to be erected in South Wales. These must have been described in considerable detail for Lammot noted that 'If he does not send me the drawing, I will draw it from his description'.

Mr. Merrick, one of the owners, was Lammot's guide through the Roslin Mills when he arrived there on 8 March. The firm had began in 1803, the year the Du Pont mills were under construction, and had added newer works in 1820 and 1854. Du Pont had expanded its Brandywine operations during the War of 1812 and again in the early 1840s.

A feature that caught Lammot's eye in the Roslin refinery was the draining of the clarified liquid saltpetre through sixteen thicknesses of white flannel to ensure its purity before it crystallized. Sulphur to be used in making the best quality sporting powder was sublimated twice, the pulled material being sold to vitriol manufacturers. Samples of the refined saltpetre and sulphur were given to him. Charcoal was made from English dogwood from which all knots had been bored out, each piece being washed and wiped by women workers before going into the kilns.

The ingredients were crushed and given a preliminary mixing under lightweight edge runners, but run dry, in Lammot's opinion a dangerous procedure. The mills were built of heavy cut stone, the machinery was well made, and the gearing in most of the mills was placed under the mill floor, features he thought superior to the Dartford Mills. Blasting powder was rolled for four hours, sporting powder for eight hours, the runners making eight revolutions per minute.

Pressing, granulating and glazing were all done in one building. Only six trays, or layboards, of powder were pressed at a time by a hydraulic press driven by a pump, instead of the older screw press

used at Dartford. Glazing was done by tumbling in barrels but Mr. Merrick added no black lead for he did not believe it improved the quality of the powder.

Roslin's dry house was an octagon shaped building with a stove in the middle. Frames built into the walls held racks covered with canvas on which the powder was spread to dry. Roslin did its own coopering, making barrels and kegs ranging from 100 lb. to 5 lb., and packed its best sporting powder in 1 lb. and ½ lb. tin canisters. Most surprising to Lammot, to open a keg the head had to be knocked in for there was no bung hole in either bilge or head from which to pour the powder.

Queried about the strength of the cannon powder he made for the government, Mr. Merrick informed Lammot that a charge of two ounces was expected to hurl a 68-pound ball from a mortar eprouvette a minimum of 250 feet; the U.S. Ordnance Bureau standard at that time required a charge of one ounce of powder to throw a 24-lb. ball a minimum of 250 yards.

In their parting conversation Mr. Merrick told Lammot that the price of blasting powder in the 25-lb. kegs had recently been reduced two shillings, 'and the agreed price for March, April and May was 54 shillings'. The term 'agreed price' suggests that Scots powdermakers were engaged in price fixing in 1858.

The Kames Powder Company at Ilsen, Kyles of Bute, was Lammot's next call, where he arrived the following morning after spending the night in Glasgow. It was a cold, snowy day and he walked the three miles from the boat landing to the mills in twenty minutes. The managing director, a Mr. McCullum, was in Glasgow but his son Duncan took his American visitor through the mills.

The entire plant, including the director's and twenty workmen's houses, was surrounded by a seven-foot stone wall. All the mills were of heavy stone construction, one side open, with a corrugated iron roof laid on but not fastened. Both water and steam were used to drive the machinery, with greater reliance on steam power in this cold climate where ice was common. All the gearing was encased in wood, something Lammot had never seen, but obviously a protection against the severe Scottish winters. A pound of Kames' best quality musket powder was given to Lammot as a parting token. He thought it flinty, coarse, badly glazed, and the grains too large, about the size of Du Pont ordnance powder.

On his way back to Glasgow Lammot learned what may have caused the Kames powder to be of dubious quality. Returning with him was a Daniel King of the Camlachie Chemical Works, a Glasgow firm that supplied Kames with its charcoal. This was not pure charcoal but 'consolidated' charcoal, half charcoal and half coke. King swore du Pont to secrecy about this, stating that Kames preferred it because it incorporated better with sulphur and saltpetre than did regular charcoal.

On his return to London Lammot sought permission to visit Woolwich Arsenal to learn what he could about recent developments in British ordnance. In America experiments had been under way for some years to perfect both smooth bore and rifled cannon of larger calibre, principally the work of Captain Thomas J. Rodman. Regular cannon powder, however, had not proved satisfactory in testing the new guns, often bursting them by high pressure created in the breech at the instant of ignition. Du Pont and other powdermakers were faced with the task of making a slower, progressive burning propellant powder that applied its energy throughout the length of the barrel yet would still give the desired velocity to the projectile. Lammot seemed aware that the powder used in English 10- and 12-inch guns performed satisfactorily with few mishaps, and it was his desire to learn more about this that led him to Woolwich.

Special permission had to be obtained to gain admittance to the arsenal so he went to the U.S. Ministry seeking the assistance of U.S. Minister George Mifflin Dallas. Dallas could not help him: he had had three identical requests in recent months but the English authorities had turned him down in every instance. He was annoyed at these rebuffs but, if Lammot insisted, he would try again: however, he should not expect an answer in less than ten days. Not one to be patient with bureaucratic delay Lammot said he would try other channels. The secretary of the U.S. Legation, Benjamin Moran, who had first greeted Lammot, penned this brief description of the American powderman in his journal[9]

> Lammot du Pont of Delaware, one of the powder family, called to see us for a pass to Woolwich, but we could not give it. He is a tall young fellow wearing spectacles, walks clumsily, but talks well and is gentlemanly.

While waiting for responses from several individuals who might secure him admission to Woolwich, Lammot went to the Patent Office to see what patents on explosives had recently been filed. For a shilling each he bought copies of twenty of the newer gunpowder patents, including drawings and specifications, and paid for four others which had been filed but for which copies were not yet available; these were ordered to be sent to him in the United States. Some might be of no use, he wrote his Uncle Henry '. . . yet there are some curious ideas patented and it will give the various patents under which the English manufacturers are working'.

With time on his hands while awaiting word on Woolwich, Lammot did some sightseeing in London, one stop being the Crystal Palace which he characterized as a '. . . humbug, although extremely handsome. Yet the machine department contains nothing worth seeing except a gold crusher and a couple of steam engines. All the rest are washing machines, etc., etc., and Yankee notions put there as advertisements'. In retrospect, as he reviewed his journal in the quiet of his room at Morley's, recalling the features of the mills visited thus far, he offered the opinion to his Uncle Henry, 'From what I have seen of the mills here they are far *behind us*'.[10]

Admittance to Woolwich for a limited tour finally came, but only after being '. . . cross-questioned as to my *pedigree*. I had entered my address as Morley's Hotel, but I confessed I was a barbarian from the States, and was escorted by a Bumaladdy to Cap't. Boxer's office'. Happily the superintendent, Major-General Edward M. Boxer, proved an affable person, indeed complimentary, for he told Lammot that Du Pont's and a Belgian powder were the only foreign powders that gave satisfaction at Woolwich. Another officer who joined them admitted that Du Pont's musket powder was as good as the English, but there was so much prejudice against foreign powders they had been used only for blasting and filling shells.

The size of Woolwich and its bustling activity amazed Lammot. The ground extended over five miles, and at the wharves 22 vessels were loading and unloading simultaneously. There were tremendous stores of ammunition and weapons; in one long row he saw 600 8-inch 68-pounder mortars. He also saw what might have been intended as England's 'secret weapon' to batter down Russian fortifications in the Crimean War. This was a 3-foot mortar designed to hurl projectiles of 26 cwt. a distance of five miles when fired by a powder charge of 180 lb. (figure partially illegible). The tests, however, had proved disappointing, Major-General Boxer informed him: 'With 40 lb. of powder at 45° angle she threw 100 yards only and broke her fastenings. The shells penetrated 16 feet in the marsh . . . They use a derrick to load the mortar and another to hoist the shells out of the ground. They say she is a failure'. The visit was far too restricted to satisfy Lammot.

Next on his itinerary were the Maresfield Powder Works near Lewes in Sussex, the firm in which Henry E. Drayson, who had visited the Du Pont mills the previous November, had said he was a partner. Drayson was not on hand to greet Lammot, his absence being quickly explained by the superintendent of the plant, Frederick G. Spray, the managing partner. Drayson, he told his visitor, had spent time in prison for forgery and other misdemeanors, and had not been connected with the business for the past 18 months. Recalling that Drayson had tried to sell his firm a new powder-making process (Patent No. 2427, 31 October, 1855), which now was revealed as not his to sell, Lammot excoriated him as a 'Damn rascal!' – his strongest written epithet.

A new method for making black powder in which the three ingredients were boiled in a vacuum pan had recently been developed by Mr. Spray and patented by the Maresfield Company (Patent No. 2983, 1 December, 1857). As it was explained to Lammot he recognized in it some similarities to a vacuum process he had experimented with four years earlier but which had been discarded as uneconomical. The English technique produced a good powder, as a demonstration soon proved, but Lammot became cautious when Mr. Spray stated that if the Du Pont Company wanted to purchase the American rights to it, all negotiations had to be with him personally, not the company. 'This looks bad', Lammot noted in his journal.

The superintendent conducted some comparative firing tests on a mortar eprouvette firing a 6-lb. ball with 2 ounces of powder. Du Pont's superfine Eagle powder hurled the ball 430 feet, but the new Maresfield powder topped this by well over 200 feet, the ball going 662 feet. Other powders, all English, threw it varying distances from 320 to 450 feet. The Maresfield powder was also the cleanest, leaving the least residue in the gun; Du Pont's was second, but it made the most noise.

Lammot sensed a reluctance in Mr. Spray to take him through all the mills, so he did not press his

host. But he was shown an improved glazing barrel which Mr. Spray claimed cut glazing time from six hours to two. The barrel was really two barrels, a smaller inner barrel with 6-inch wooden pegs or tines projecting from its exterior that revolved within a larger barrel holding the powder. The inner barrel turned at 50 rpm and the outer at 25 rpm. Lammot was assured that the shorter running time did not affect the quality of the powder, samples of which he later obtained from Maresfield's London agency.

On his return to London he was pleased to find a letter from Major-General Boxer at Woolwich introducing him to Major J. Frazer Baddeley, superintendent of the Waltham Abbey Mills. Here he would be less a stranger for he had prepared himself by reading the memorandum his uncle, James Bidermann, had written when he had visited the mills in 1838.[11] But the tour of the Royal Gunpowder Factory was disappointingly brief. Certain areas were forbidden to outsiders; even Major Baddeley did not have the authority to take him into these places until permission was first obtained from the Ordnance Board in London. He was shown some new rolling mills, all driven by a double cylinder, high pressure steam engine powering a single shaft that passed through an arch beneath the floor of each mill. Lammot made special note of one of the safety devices which consisted of 'an arrangement so that when one mill of the set blows up it loosens a catch and upsets about 3 cubic feet of water on the platform of each of the mills that did not blow'.

Some time was spent in a well-equipped workshop containing many machines and tools used to construct and repair all types of powder mill equipment. Of special interest was a boring mill capable of turning the large iron edge runners and bed plates of the mills. Whether he realized the wisdom – the economy, control and time saved – of having such a facility in the Brandywine mills we have no direct knowledge, but two months after he had returned home a large machine shop was under construction in Du Pont's Hagley Yard.[12]

At the office of the Ordnance Board in London he was told it would take a week to act upon his request to see the rest of Waltham Abbey. His frustration at the leisurely pace of the English business man made him exclaim, 'The London days are very short, nothing done before 10 and nothing after 4 o'clock in the afternoon'. This allowed him time for only one call a day unless several appointments were in the same town. And, he complained to his mother, 'Travelling in England costs something, say $15 per day. If you look at a man he will ask you for a shilling, and nothing is free'.

> [The next three weeks, from March 29 to April 18, Lammot spent in France visiting relatives, the government refinery in Paris, and powder mills at Le Bouchet in Seine-et-Oise, Ripault near Tours, and Esquerdes near St. Omer. He purchased some laboratory equipment from M. Bianchai of Paris, 'a great apparatus man', one item being a mercury densimeter, of which '. . . there is not one in our country', he noted. Thirty-three pages of his journal chronicle this stay in France, plus visits to Belgium's Royal Powder mill at Wetteren near Ghent, and the Prussian government's mill at Spandau. There is much interesting material, both technological and personal, about his stay on the Continent, but to recount this even in condensed form would over-extend this paper and detain us too long outside the British Isles to which he returned on April 19.]

On Monday, 20 April, Lammot was in Sheffield calling upon Dixon and Sons, a metal processing firm, seeking a supply of canister stoppers and powder flasks. But Dixon stamped its name on all its products and its prices were too high. He was advised to try some firms in Birmingham where he might obtain stoppers and flasks of cheaper price and quality, 'Brummagen' ware.

Instead, being near Liverpool, Lammot decided to accept the invitation of a Mr Henry Unkles, whom he had met earlier in London, to visit the Ballincollig Powder Mills on the River Lee near Inniscarra, not far from Cork. During the Crimean War the government had erected new mills here and leased them to private operators, one of whom was Mr. Unkles who had informed Lammot that they had '. . . the best machinery in the *World* ', a superlative that sharpened the American's curiosity.

Not finding Mr. Unkles at home in Cork, Lammot rode the six miles to the mills where he introduced himself to the superintendent, Sir Thomas Tobin.[13] Tobin was courteous and willing to discuss the powder business and some aspects of Ballincollig's operations, but he would not take Lammot through the mills. The general impression given was that Ballincollig was patterned after Waltham Abbey, was similarly equipped and using the same procedures.

The water power of the River Lee, the only millstream Lammot had yet seen comparable to the Brandywine, turned huge stones incorporating edge runners 7 feet in diameter, each weighing

20,000 lb., exceeding in weight any Lammot knew of. They were in operation night and day, producing mostly blasting powder for which there was heavy demand. Twenty-five tons of saltpetre were refined weekly. Materials were moved from mill to mill via boats on the mill race. Fifty-five coopers were employed making barrels and kegs, and the finished powder was hauled from the mills in wagons, each with a capacity of 200 25-lb. kegs, roughly comparable to the loads carried by the larger Conestoga wagons, still the common carriers of powder in America. Lammot's note that the Ballincollig's kegs '. . . are smaller than ours but they put in full weight' is subject to several interpretations. A very literal reading implies that Du Pont gave short weight in its packing; the second, that it made its kegs a little larger, with some free space to allow the powder to tumble about in the kegs when they were periodically rolled to prevent the powder from caking while in storage.

Tobin gave him samples of blasting powder and of a new kind of powder which had been invented in France. Lammot described it as 'a kind of sawdust'; reportedly it performed very well sometimes, at other times very badly. But it seemed worth looking into '. . . for from its appearance it might be made cheap enough to supersede powder'. He ended his visit by driving around the outside of the Ballincollig establishment and then went off to see Blarney Castle. He fails to note whether he kissed the Stone.

The time was drawing near for his return home and he had not yet succeeded in seeing those parts of the Waltham Abbey Mills from which he had been barred on his previous visit. On 27 April he wrote to U.S. Minister Dallas boldly stating he thought it was his obligation to assist an American manufacturer whose product was so important to American security:

> As you are probably aware I am engaged in one of the principal powder factories in our country and have been on a tour to examine in what respects we are behind the European nations. I have been through the most important private works of England and Europe which manufacture principally for commerce. But I am very anxious to see the government mills of England where they manufacture nothing but cannon powder . . . As we are the principal contractors for our government I think there can be no objections to requesting a permit as it is the duty of our government to aid rather than discourage our manufacturers in endeavouring to gain knowledge. I should have brought letters from the government to you, but I am still trusting to your appreciation of our troubles.

With little confidence such prodding would bring the desired result, Lammot went to the War Department office and filed a direct application to be admitted to Waltham Abbey. Through the good offices of Henry Byham of the War Office a permit was soon issued to him and he went to the mills on 30 April.

Neither Major Baddeley, the superintendent, nor any other officer was available as guide, so the foreman of the mills who knew 'nothing but the routine of the manufacture' was assigned to him. He was first shown how saltpetre was refined by a new process set forth in a recent aide-memoire; sulphur was doubly refined, the second time by a method of distillation Lammot had not seen elsewhere. Charcoal was usually made from willow and alder but some experiments were being made using English dogwood. Filling the cylinders and loading them into the horizontal ovens above the furnaces was expedited by use of a rail track and rollers. In the press house an endless belt fed powdercake on to breakdown rolls before it went into a hydraulic press to be compressed between plates of gunmetal, a material Waltham had found more durable than wood.

He was much impressed by the granulating machine, declaring it to be 'decidedly the best granulating machine in England or Europe'. It had been built at Woolwich at a reputed cost of £2,000 and it could granulate 8,000 lb. of powder daily, a more complex and efficient machine than the simple device his uncle James Bidermann had seen here twenty years earlier.

Glazing barrels were made of mahogany, 5 feet long and 2 feet diameter, each with a capacity of 270 pounds. Cannon powder was glazed for four hours, musket for six, and then rolled again in reels or bolters to sift out the powder dust. Drying was done in wooden trays with canvas bottoms against which a current of air was directed, a method Lammot had first seen at the Le Bouchet mill in France.

He was given a sample of a new, large grain coarse powder hopefully designed for a more successful firing of the 'monster' mortar he had seen at Woolwich. His guide also gave him samples of musket and cannon powder, and of a slow-burning powder developed for use in the Enfield rifle. Nine pages of notes and observations illustrated with crude sketches of equipment and parts of machines, provide

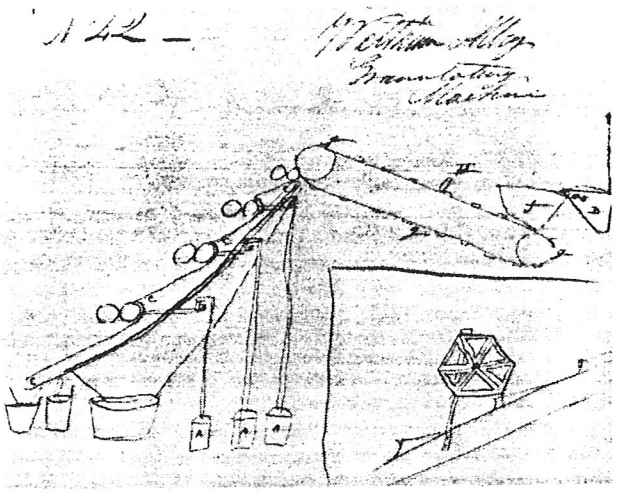


Fig. 3. Granulating Machine at WALTHAM ABBEY. Lammot du Pont's sketch of what he called 'decidedly the best granulating machine in England or Europe'.
Courtesy of Eleutherian Mills Historical Library.

a meticulously technical picture of every step in making powder at Waltham Abbey, the prime objective of his stay in England, where he spent four days, from 30 April to 3 May.

On 5 May Lammot boarded the steamship *Fulton* at Southampton, bound for New York. His baggage contained samples of raw and refined materials, finished powder, copies of patents, mill and machinery drawings, pistol eprouvettes, canisters, labels and trade cards, laboratory apparatus (with some special pieces ordered in Paris to follow), and his 104-page journal with rough marginal sketches of machines and other mill equipment. When only three weeks into his tour he had written his uncle, 'I am a poor hand at describing, but I have taken notes of all I have seen and can explain it when I return . . .'[14] Soon, in the small stone office building that was company headquarters he would be showing and explaining to brother Irenée and Uncle Henry what he had gathered and learned during his sojourn in Europe.

Had the purposes for which Lammot made the trip been realized? Did consequences of any import to Du Pont powdermaking technology result from it? In retrospect, upon returning home was he still of the same opinion he had stated in his letter of 16 March to Uncle Henry that '. . . they are far behind us?' Could he corroborate, or would he now refute the assertion of Henry Drayson, the English powdermaker who had visited the Du Pont mills the previous November, that it would be time wasted visiting European mills with the hope of learning anything new in powdermaking techniques?

Unfortunately no summary evaluation of his journey has been found in his surviving papers or those of the company or his partners. The only subsequent mention of it occurs in a letter written by Lammot's Aunt Eleuthera, a neighbor and shareholder in the firm, to a relative in France:

> In the three months he was absent he has contrived to see more than I ventured to hope, besides accomplishing successfully the object of his journey.'[5]

This paper is printed as it was read to the Society. Another version, entitled *An American Powdermaker in Europe* . . . has been deposited in the Science Museum Library. It includes Lammot du Pont's visits to mills on the Continent and a substantial addendum with sketches of equipment which are unsuitable for reproduction. (Ed)

NOTES

1. E. I. de Pont de Nemours & Co., Ledgers, 1850–1855, Accession 500, Eleutherian Mills Historical Library, Greenville, Delaware. All manuscript citations will be from collections in this repository, abbreviated EMHL, unless otherwise indicated.

2. Patent No. 17,321, 19 May, 1857: U.S. Patent Office.

3. Eleuthera (du Pont) Smith to Lilia Bienayme, 6 July, 1857. Bienayme Family Correspondence, Acc. 521, EMHL.

4. Lammot du Pont Papers, Accession 384, Series B, EMHL, hereafter cited as Acc. 384, EMHL.

5. 'Memoranda on Powder Mills'. ibid.

6. Notes and Collections of Bessie G. du Pont, Longwood Manuscripts (hereafter LMss), Group 7, Series F, EMHL.

7. Journal of Trip to Europe kept by Lammot du Pont. February-May, 1858. LMss, Group 5, Series A. EMHL. The remainder of the article is taken from this journal unless another source is cited.

8. Mrs. A. V. du Pont to Lammot du Pont, 21 February, 1858, Acc. 384. Series B, EMHL.

9. *The Journal of Benjamin Moran*, 2 vols., edited by Sarah A. Wallace and Frances E. Gillespie. (Chicago: University of Chicago Press, 1949), I, p. 266.

10. Lammot du Pont (London) to Henry du Pont, 16 March, 1858, LMss, Group 5, Series A, EMHL. The Crystal Palace housed some of the exhibits that had been in the Great Exhibition of 1851.

11. *Memorandum on Waltham Abbey Mills*, by James A. Bidermann (1838), Acc. 384, Series B, EMHL.

12. *Delaware Gazette*, 13 July, 1858.

13. Sir Thomas Tobin (1807–1881), a member of the Royal Irish Academy, visited the United States during the latter part of 1862. While en route from Philadelphia to Washington he noted in his journal: 'I knew that Du Pont's Powder Mills were on Brandywine Creek, and like the old hunter who loved the crack of the whip, I must see them'. Ms. 4110, National Library of Ireland, Dublin. I am indebted to Mr. George D. Kelleher, Inniscarra, Co. Cork for bringing the Tobin journal to my attention.

14. Lammot du Pont (London) to Henry du Pont, 16 March, 1858, LMss, Group 5, Series A, EMHL.

15. Eleuthera (du Pont) Smith to Lilia Bienayme, 26 May, 1858, Acc. 521, EMHL.

DISCUSSION

Mr. P. N. WILSON enquired why Elterwater mill was one Lammot du Pont decided to visit. It was small and thoroughly backward. In 1840 an accident there had killed five, and later in 1878 another killed three. Wakefield's mills were larger and more modern, as was the Gateback works who in 1865 began making their own saltpetre.

Mr. REX WAILES was delighted to have heard paper. Fifty years ago he had visited the Curtis and Harvey mill at Faversham. The mills were of the overdrive type. Each mill was on its own island, and surrounded by earthen walls. The whole factory ground was planted as an orchard, which provided applewood for the teeth of the cogwheels. The mill was taken over by Nobel's and closed down, when he made a second visit. Just before the war the Soviet Trade delegation had tried very hard to obtain a photograph of the mill from his father.

Dr. N. B. WILKINSON said that Cuban hardwoods and lignum vitae were used for the wearing parts of the du Pont machinery.

Mr. M. T. WRIGHT said that English nineteenth century accounts mention the drying by steam pipes or glooms – red hot pipes with shields. In Phil. Mag. 1801 vol. 9 there is an account by Coleman of Waltham Abbey on powder making machinery. Aitken's Dictionary of 1807 notes that Best Fine Battle powder was still being incorporated by wooden pestles, the powder being pelleted by squeezing as a stiff paste through a sieve. Also Fairbain: Vol. 2, 1863, on Mills and Millwork mentions the underdriven mills at Waltham Abbey.

Dr. N. B. WILKINSON wished that mill builders had recorded changes with their dates. One of the objects of the Eleutherian Mills Hagley Foundation is to encourage the preservation of business records and possibly deposit them with Hagley.

Mr. P. N. WILSON said that the corning mill at Waltham Abbey mentioned by Dr. Wilkinson was probably designed by Congreves. Two men of that name were directors of Waltham Abbey, and it was probably the younger one who devised the corning machine.

Mr. J. W. BUTLER remarked that Dr. Wilkinson had given three papers in one. The picture of du Pont showed a more pleasant looking man than might be gained from reading his journal. He asked how much of the four pounds of powder bought by du Pont was taken away with him.

Dr. N. B. WILKINSON said that he took back an array of many things, including: powder samples, laboratory apparatus, lables, cannisters. The manifesto of the matenal survives. The four pounds of powder was probably used up in swapping samples with makers.

AN AMERICAN POWDERMAKER IN EUROPE: LAMMOT DU PONT'S JOURNAL, 1858

By Norman B. Wilkinson

"I am a poor hand at describing, but I have taken notes of all I have seen and can explain it when I return, but from what I have seen they are far behind us."[1] Despite this modest opinion of his exposi-

[1] Lammot du Pont (London) to Henry du Pont, March 16, 1858. Papers of Lammot du Pont (hereafter Acc. 384), Series B, Eleutherian Mills Historical Library, Greenville, Delaware. Repository hereafter cited EMHL.

tory talents Lammot du Pont's "notes" comprise a very detailed journal of 104 pages kept during a three-month trip to visit powder mills in England, Ireland, France, Belgium, and Prussia which he made between February and May, 1858. St. Petersburg in Russia was on his itinerary but he did not get there.

There were ample family precedents for this twenty-six-year-old junior member of the Du Pont Company going abroad to observe the most recent improvements in the technology of Europe's black powder mills. In 1801, his grandfather, and founder of the company, Eleuthère Irénée du Pont (1771-1834), had gone back to France for a three-month "brush-up" before erecting his powder factory on Brandywine Creek, near Wilmington, Delaware.[2] In Paris he had met with officials of the Arsenal

[2] See "Brandywine Borrowings From European Technology," by Norman B.

Wilkinson, in Technology and Culture, Vol. IV, No. 1, Winter, 1963.

and the Régie des Poudres, the government powdermaking bureau. He had visited refineries and powder mills where he examined new machines and where improved processes developed during the revolutionary war years were explained to him. By these means E. I. du Pont had been brought up to date on the latest methods of the Régie des Poudres for which he had worked as a young man from 1787 to 1791. This information and some equipment supplied by the French aided considerably in the success of his own enterprise. In less than ten years it was recognized by Secretary of the Treasury Albert Gallatin as "the most perfect establishment for making powder in America."[3]

[3] Quoted in the American Watchman, June 2, 1810.

Pierre Samuel du Pont de Nemours (1739-1817), his father, who had returned to France in 1802, supplied him with technical journals, treatises, memoranda, and reports dealing with refining techniques, charcoal burning, and tests of new machinery. And when a two-volume work, Traité de l'art de fabriquer la poudre à canon, by Bottée and Riffault, high officials in the Régie des Poudres, appeared in 1811, Irénée urged his father to send him a copy because "...its many details of the improvements made in France may be most useful to me."[4]

[4] E. I. du Pont to P. S. du Pont de Nemours, n. d., 1812, Papers of Eleuthère Irénée du Pont (Longwood Mss., Group 3),Series A, EMHL.

In 1837-1839 another member of the Du Pont firm, James Antoine Bidermann, a son-in-law of the founder, made a long sojourn in Europe

gathering information on recent improvements in powdermaking. No comprehensive work such as Bottée and Riffault's had been published since 1811, but he sent home pamphlets, reports and memoranda on recent experiments with cannon powder, new powder-testing methods, and improved techniques in making charcoal. He described what he saw at England's Waltham Abbey Mills and at some of the government mills in France. Alfred Victor du Pont, head of the firm beginning 1837, wrote him that "in an establishment like this it is essential that we keep ourselves informed of whatever is new in our line."[5] Copies of what he had retained over the years Bidermann now gave to his nephew Lammot as the latter was preparing to leave on a similar mission in January 1858.[6]

[5] Notes and Collections of Bessie G. du Pont (Longwood Mss., Group 7), Series F, EMHL.

[6] James A. Bidermann to Lammot du Pont, Jan. 26, 1858, Acc. 384, Series B, EMHL.

Readily available to E. I. du Pont, to his son Alfred Victor (1798-1856), and to his grandson Lammot, were a number of editions of the Aide-mémoire à l'usage des officiers d'artillerie de France, manuals containing information on the manufacture of black powder and ordnance. Officers of the U.S. Bureau of Ordnance who had visited European mills and arsenals during the 1830s and 1840s and whose duties brought them to the Brandywine mills were other sources of information about changing explosives technology. It was from one of these, Captain A. Mordecai, that Alfred Victor du Pont in 1846 had first heard about guncotton, an explosive that temporarily threatened to replace black powder, discovered

by a Swiss professor of chemistry, Christian Frederick Schoenbein. Du Pont was the first to make and test it in this country but decided against producing it because it was too dangerous, very costly to make, and apt to corrode or burst gun barrels. In Alfred's opinion it had possibilities as a blasting agent if it could be made more economically.[7] Du Pont continued,

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[7] Du Pont Co. to Gardelle and Rhind, Augusta, Ga., Dec. 4, 1846; to A. C. Cazenove, Alexandria, Va., Dec. 7, 1846; to Captain A. Mordecai, Dec. 9, 1846. All in Records of E. I. du Pont de Nemours & Co. (Acc. 500), Du Pont Co. Letterbook, 1846, pp. 201, 204, 210, EMHL.

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sporadically, to test guncotton's possibilities in the laboratory. In 1850 at his father's direction, the nineteen-year-old Lammot, graduated the previous year from the University of Pennsylvania with a major in chemistry, made a small amount, cautioned in advance by his father that he "would be very likely to blow himself up."[8]

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[8] Alfred V. du Pont to John S. Twells, Philadelphia, April 24, 1850, Papers of E. I. du Pont de Nemours & Co. (Longwood Mss., Group 5), Series A, EMHL.

Lammot survived this hazard and continued to test and experiment with the raw materials of black powder and processes for converting them into better explosives in the refinery laboratory and in his own workshop. His career in the family business began at a propitious time for it coincided with increasing demands for black powder from railway construction contractors, from the Pennsylvania anthracite coal mines, from hunters and westward migrants, and from the mid-western iron and copper mines. The Du Pont Company had also supplied military powder to both belligerents of

the Crimean War, 1853-1856. From annual sales of $258,586 in 1850, by the end of 1855 sales had risen to $694,814, the highest they were to reach until the threat of civil war in 1860.[9]

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[9] Du Pont Co. Ledgers, Acc. 500, EMHL.

A major effort of American explosives manufacturers was to find a cheap, effective substitute for potassium nitrate, saltpeter (KNO_3), from India which constituted about 75% of black powder, and was available only through British brokers who controlled the trade. Lammot worked on this and in 1857 perfected and patented a process using sodium nitrate ($NaNO_3$), South American saltpeter, in place of the Indian potassium nitrate.[10] It could be bought at about half the price of the latter,

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[10] Patent No. 17,321, May 19, 1857, U.S. Patent Office.

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and was not as readily subject to the vagaries of British imperialist policies which could shut off shipments to the U.S. in times of crises. Named "B" blasting or soda powder, Lammot's improvement meant lowered production costs for powder used in the burgeoning extractive and excavating industries, giving promise of a decided advantage to his firm in these markets. However, it was too hygroscopic, moisture-absorbing, for military powders, so potassium nitrate continued as the main ingredient in cannon and rifle powder until guncotton and smokeless powder were perfected in the 1880s.

Whether Lammot's trip was recognition or reward for this achievement we do not know, but it was first mentioned soon after "B" blasting powder had been patented. His aunt Eleuthera (du Pont) Smith, who lived close by Nemours where Lammot lived with his mother, in early July 1857

informed a cousin in France that it was being talked about within the family circle. She was anxious he should go for he needed a change: "His life is a very arduous one and he is, I think, overtasked. He superintends the department of saltpeter refining and burning the charcoal....He is 26 years of age, & a most exemplary young man. We all love him dearly."[11]

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[11] Eleuthera (du Pont) Smith to Lilia Bienaymé, July 6, 1857, Bienaymé Family Correspondence (hereafter Acc. 521), EMHL.

Preparations began in mid-summer of 1857 when letters of introduction were given to him by Captain Mordecai of the Ordnance Bureau, by Uncle James Bidermann, by Emile Geyelin, a Philadelphia turbine manufacturer, and by the New York merchant house of Grinnell, Minturn & Co., which had handled powder shipments from this country during the Crimean War.

But Lammot evidently considered his visit of such importance to America's future security that he solicited a general letter of introduction from President James Buchanan through a friend and nephew of the president, J. Buchanan Henry, which read:

> Being about to start for Europe with the view of examining powder mills, especially those which manufacture war powder, which on the Continent are all under control of their respective governments, I would respectfully solicit from Your Excellency such letters of introduction to our ministers at Paris, Berlin and St. Petersburg as will induce them to secure for me access to the same. Being a practical powder manufacturer I hope to be able to return

> with some information which may be useful to our Government in regard to its supplies of gunpowder.

Several rough drafts of this request were written before the final version was sent off. In these Lammot noted, but deleted from the letter sent, that the Du Pont Company supplied the U.S. Army and Navy with half their powder needs; that bursting cannon had been a fairly frequent occurrence in recent years; and that, although U.S. Ordnance officers had on occasion visited European powder mills, little had been learned because "they were never of great ability."

President Buchanan responded with this letter of introduction which Lammot was to present to the U.S. ministers when he arrived in Paris, Berlin and St. Petersburg:

> The bearer hereof, Mr. Lammot du Pont, of the firm of Du Pont de Nemours, powder manufacturers of Wilmington, Delaware, being about to visit Russia, France, and Prussia for the purpose of examining their respective powder mills with a view to the improvement of the manufacture of gun powder for military purposes, it gives me pleasure to afford him this testimonial of my consideration and to ask in his behalf the friendly cooperation of our Ministers in facilitating his access to all the sources of information which may be within their power.[12]

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[12] Letters of introduction and related correspondence, all in Acc. 384, Series B, EMHL.

News of the pending trip circulated fast within the prolific and widespread family. Alfred Victor II, Lammot's younger brother, a powder agent and paper manufacturer in Louisville, Kentucky, expressed the wish that he "was out of business and could join you....When you once get over there go and see everything...there is no use of hurrying back, as it is not likely you will be over the pond again soon. What steamer do you take, Collins or Cunard?"[13] The answer to the last was furnished by his brother-in-law Peter Kemble in New York City, husband of Lammot's sister Victorine, who booked passage for him August 24 on the Collins Line steamer Adriatic, with the understanding it could be cancelled if circumstances made it necessary.[14]

[13] Alfred V. du Pont to Lammot du Pont, August 19, 1857, ibid.

[14] Peter Kemble to Lammot du Pont, August 24, 1857, ibid.

Cancellation was made necessary by a tragic accident that postponed Lammot's trip until the following year. This was the untimely death of Alexis I. du Pont (1816-1857), Lammot's younger uncle who shared direction of the mills with Henry du Pont. A mill exploded and caught fire on Saturday, August 22, killing five workmen. Burning embers flew through the air and fell on the roof of a press house containing tubs of powder. As Alexis was mounting the roof to douse the flames the press house blew up hurling him onto powder drying tables nearby. The concussion and severe burns were fatal, and after suffering an agonizing twenty-four hours he died.[15] His nephew was the obvious person to assume

[15] The Life of Alexis Irénée du Pont, 2 vols. Edited and compiled by Allan J. Henry, 1945, v. 1, pp. 1-12.

Alexis' responsibilities.

The European trip might well have been postponed beyond early 1858, had the powder industry not been affected by the generally depressed business conditions. Du Pont's sales dropped 28 percent in 1857 and another 7 percent in 1858. If sales had continued at the levels of 1855 and 1856 it is doubtful that Lammot could have been spared, but it was decided he should leave early in the new year.

During this interim he had opportunity to learn something in advance about the powder mills he planned to visit overseas. Early in November 1857 a Henry E. Drayson, co-owner of the Maresfield Powder Company in Sussex, called at the Du Pont Company office. Drayson had been through all the English mills that made sporting powder and his father had for forty years been superintendent of the government mills at Waltham Abbey. He described for Lammot and his Uncle Henry some of the principal features at his own and other mills, e.g., the number and size of rolling wheels, length of time for rolling or incorporating powder, daily outputs, types of containers, shifts to steam power, and the introduction of new types of glazing barrels. This discussion preceded his tour of the Du Pont mills, for after going through them he stated, "there was no use in any of us to go to Europe as we could not learn anything." To which Lammot added his footnote: "This was a piece of Blarney which might be interpreted into stupidity."[16] Young du Pont had a sense

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[16]"Memoranda on Powder Mills," by Lammot du Pont, Acc. 384, Series B, EMHL.

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of history. Europeans had been making black powder for six hundred years, Americans for scarcely a century; despite the technological "leap forward"

this country had made in recent decades Lammot was aware that long experience could not be overlooked as a teacher.

The crossing on the Cunard Liner Arabia was meticulously recorded on loose, blue, legal size sheets by Lammot, except during his occasional bouts with mal-de-mer. Departure was at 9:50 a.m., Thursday, February 17, and land was lost sight of at 12:10 as the sea roughened. One of the thirty-seven passengers who had made twenty-two crossings assured Lammot this was its usual state, a little unsettling to a first tripper. And it must have been more unsettling to the captain a few days later when, while smoking a cigar with Lammot, his passenger told him that his luggage contained four pounds of gunpowder! The captain immediately ordered it stowed in the ship's magazine.[17]

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[17] Journal of Trip to Europe kept by Lammot du Pont, February-May, 1858. Longwood Mss., Group 5, Series A, EMHL. The remainder of this article is taken from the journal unless otherwise indicated.

On the tenth day Holyhead was sighted, a pilot taken on board, and landing made at Liverpool in early evening. The customs inspection, Lammot noted, was "a farce." Liverpool, in his eyes, was a dirty and disagreeable place, the buildings giving the impression they had been built to last a thousand years. He put up at the Adelphi Hotel. The next day he presented himself at the office of Brown, Shipley & Co., a Wilmington-related firm of merchants, to whom a letter of credit had been sent against which he could draw funds as needed.

His first effort to visit an English powder mill was unsuccessful. After waiting two days for an answer to his request to see the Elterwater Powder Co. plant, near Ambleside, Westmoreland, he was denied

admission because it was considered too dangerous, not because the proprietors "had any jealousy against us," Lammot wrote disgustedly. He took a late afternoon train to London, buying the weekly excursion round-trip ticket that cost twenty-one shillings rather than the regular one-way ticket that cost thirty-eight shillings; his sense of economy, and maybe a wish to please Uncle Henry, impelled him to record this saving of seventeen shillings. In London his headquarters was Morley's Hotel.

Armed with a letter of introduction, on March 6 he rode to Dartford in Kent, twenty-five miles southeast of London, to the powder plant of Pigou and Wilks. Here he was received in friendly manner by Mr. Wilks who kept him in conversation for an hour recounting the history of the firm, founded before the 1660s. There was no reluctance to take Lammot through the mills.

The Dart River, about twice the size of Squirrel Run, a Brandywine tributary running through the Du Pont Company's Hagley Yard, was the prime source of power to turn the mill wheels. Its fall was 7 feet 6 inches, about a third of the fall of the Brandywine available to the Du Pont mills. Supplemental power to the eight iron breast water wheels was furnished by four steam engines, described by Lammot as "condensing vertical double cylindered engines, Cornish boilers." Low water in time of drought, or ice in winter, would be the usual causes for shifting to steam power. Currently the average daily production of powder was said to be about 200 kegs (25 pounds in each). On a 24-hour schedule the mills could produce 408 kegs of blasting powder but only 102 kegs of sporting powder because it took four times as long to make. In the Du Pont mills daily production at this time averaged 800 kegs. The raw ingredients -

sulphur, charcoal and saltpeter - were ground or incorporated together by stone or iron rolling wheels for eight hours when making sporting powder, six hours for rifle powder, four hours for government and good blasting powder, and two hours for the cheapest blasting powder.

Lammot's experience as director of the Du Pont refinery made the Pigou and Wilks refining methods and equipment of special interest to him. The refinery crew at work numbered eight men but he estimated seventeen were employed when on full production. There was no laboratory for no analyses were made of the crude saltpeter nor of the discarded salts, mostly muriate of potash which was sold as fertilizer, nor of the finished, refined saltpeter. Mr. Wilks did not "understand chemistry," Lammot observed. The refinery building was a one-story structure, 60 x 80 feet, built in 1854, with a slate roof and lead gutters; rain water was collected from the roof for use in the refinery. Attached to the refinery were a crude saltpeter warehouse and a second building where the refined, crystallized saltpeter was dried. A railway ran through the three units to expedite the movement of materials. The rails were wooden but the wheels of the cars moving on them were iron. These cars had false bottoms with plugs at the side for washing the saltpeter. A first washing was done just prior to its being placed in three melting kettles, and again after long hours of boiling, clarification, and cooling had transformed it into crystals. The cast iron kettles were six feet in diameter and three feet deep, heated by furnaces immediately beneath them. As it heated, the saltpeter in solution was stirred continuously, and when melted to one part water to two parts saltpeter ("two-thirds the strength of ours," according to Lammot), glue was added to clarify or coagulate the impurities and bring them to the surface to be

skimmed off. Unwanted salts precipitated and sank to the bottom of the kettle from where they were scooped out and set aside to become the "manure" salts, or fertilizer.

The clarified, liquid saltpeter was then bailed into copper-lined wooden coolers 14 feet long, 6 feet wide, and a foot deep, from which the excess liquor was drained off as the saltpeter cooled, an operation that required three hours. This was repeated twice over into two other sets of coolers, each a foot lower than the cooler above. As the saltpeter cooled it crystallized, and workmen raked the crystals into piles on the upper slanting sides of the coolers. Lammot's eye for small detail saw that the wooden rakes or scoops were much the same as those used in the Du Pont mills, but smaller. The crystals were put into the rail cars with false bottoms, covered with water for two hours, and then the water was drained off into catch basins set in the floor between the tracks. This "dirty" water still contained a percentage of saltpeter, some of which would be recovered when used in refining successive batches of saltpeter. The final step was drying the crystals in large shallow copper pans, similar to Du Pont's drying pans, in a steam-heated dry house. The finished product was coarser than Du Pont saltpeter, containing 1 1/4 percent moisture and about one part foreign salts to 10,000 parts saltpeter. Pigou and Wilks used only Indian saltpeter, potassium nitrate, no sodium nitrate from Chile or Peru.

About sulphur, the second ingredient, Lammot did not mention where it came from, nor the method of purifying it, noting only that it was pulverized under light weight wheels weighing about 3 tons. Sicily was then the only source of sulphur and it was refined by sublimation, the process known to Lammot. Most of the charcoal was made from black alder,

lesser amounts from willow and English dogwood. There were about 400 cords peeled and stacked in the open to dry, different lots being dated to show when cut. Instead of harvesting only branches of two to four years' growth, which was Du Pont's practice with the black and crack willow it used for making charcoal, Pigou and Wilks cut down the entire tree leaving only the stump. Trunk and branches were cut into smaller pieces in a sawmill and then the bark was peeled off. Lammot noted that the grain of alder was very coarse, not unlike ailanthus, the tree of heaven.

Wood was charred in two coalhouses in horizontal cast iron cylinders three feet long and two and a half feet in diameter. The gases created were piped back into the furnaces as supplemental fuel. No mention is made of tar and pyroligneous acid, other by-products of the charring process. The finished charcoal was unloaded into iron boxes after being allowed to cool a little; care had to be taken that the cooling charcoal did not ignite spontaneously. Pulverizing the charcoal was usually done under rolling wheels but a recent improvement adopted by Pigou and Wilks was to grind it in a machine resembling a coffee mill.

Before entering the rolling mills to watch the raw materials being incorporated, Lammot and his host pulled on large rawhide slippers over their shoes as a safety precaution. There were nineteen pairs of rolling mills, one pair of stone rollers reputedly the original ones installed in the 1660s. When operating the mills with steam power Mr. Wilks calculated the consumption of coal at 1 3/4 lbs. per horsepower per hour, and that 5 to 6 h.p. was needed to turn the machinery at each rolling mill. The mills were of frame construction on three sides, the fourth side was brick, and roofs were of corrugated iron sheets 1/8 inch thick.

Such construction was much lighter than the Du Pont mills which had three stone walls, each about three feet thick, some with supporting stone buttresses and flash or baffle walls, and an open or light frame fourth side facing onto the Brandywine. If an explosion occurred, such heavy walls were designed to contain the force of the blast and vent it through the shingle or light iron roof and out the open or light frame fourth side toward the creek, keeping it away from other mills nearby. Lammot makes no comment on the English construction either from the safety aspect, the initial costs of building, or the time and costs involved in replacing a shattered building. But it must have been apparent to him that the Pigou and Wilks mills were cheaper to build and quicker and less expensive to replace if demolished by an explosion.

The gearing was an overhead arrangement with the shaft or axle of the water wheel meshing with a vertical bevel gear. This synchronized with a horizontal bevel gear which turned a pair of large spur gears; these in turn transmitted power to a central shaft to which the rolling wheels were attached. This overhead arrangement of the power train was customary in the earlier Du Pont mills, but after losing gears and shafts in a number of explosions the gearing had been placed beneath the floor of the mills where it would be less subject to the force of powder exploding above it. Most of the mills had stone rollers weighing 3 1/2 to 4 1/2 tons each; the few cast iron rollers weighed 3 tons each, about half the weight of Du Pont's rollers. The one novelty that caught Lammot's eye was the method of keeping the ingredients damp as they were being ground and mixed together. This was done by suspending a large porous bag above the ingredients tub from which water seeped slowly down dangling threads onto the powder mix beneath. In the Du Pont

mills a workman stopped the rollers and added water to the mixture whenever he thought it was getting too dry.

The powdercake from the rolling mills was taken to a press mill where it was run through grooved rollers to break it into small granules. These were loaded onto wooden trays, or lay boards, 2 feet by 3 feet in size, until a stack of powder-laden boards filled a vertical press box that held about 800 lbs. of powder. In appearance this type powder press resembled an old style paper mill press. Pressure was applied by turning a windlass which lowered a cap, or platen, onto the pile of trays; pressure was increased until the layers of powder between the boards were squeezed to a thickness of about 1 1/8 inches, giving it the necessary density. The lay boards in the Du Pont press mills were always covered with damp cloths before powder was loaded onto them, a safety measure and also an aid to compacting, but such cloths were not used at Pigou and Wilks. Lammot noted this omission, with the added observation that the Pigou press mill was the only building in the entire plant surrounded by an earth embankment, an implication that it was more prone to explosions.

The granulating, or graining, mill was a structure 18' x 30' containing two machines, one for sporting powder and the other for blasting powder. The powder chips from the press mill were fed into a hopper set above two pairs of horizontal zinc rolls, 2 feet long and 8 inches in diameter, one pair placed at a 40° angle above the lower pair. The upper rolls revolved slowly as the powder chips fell between them from the hopper and were then fed into the lower set that turned at 30 revolutions per minute, Lammot noting this was about one-sixth the speed of the Du Pont granulating rolls. As it was crushed more finely by the

lower set it flowed onto slightly inclined copper sieves vibrating twenty times a minute. The size of the mesh was appropriate to the desired size of powder being made. The grained powder and powder dust fell through the sieves onto the floor, and the oversized pieces slid down into a catch tub. The sized powder and dust were shoveled into buckets and taken to a sifting bin where the dust was screened out and separated from the grains. The dust went back to the rolling mills for reincorporation and the oversized pieces were returned to the rolls to be crushed with the next batch. New to Lammot was a safety device in the form of a compound lever that would automatically stop the machine if an object too large and too hard for the rolls to crush should fall between them.

The glazing operation was carried on in a tandem mill, a pair of mills powered by a water wheel placed between them. Each mill had four barrels, each 4 feet long and 2 feet wide, made of wood hooped with copper, having a capacity of about 250 lbs. and revolving at 45 r.p.m. These were much like "the little Eagle barrels formerly in the glazing mill in the Upper Yard," du Pont observed. Eagle was the brand name of the Du Pont Company's best sporting powder. Blasting powder was being made while Lammot was at the Dartford mills. Quarry men, Mr. Wilks informed him, liked it coated with black lead, or plumbago, because it resisted dampness in the quarry holes into which it was loaded. Depending upon the kind of powder being made the glazing time varied from four to forty-eight hours. He noted the capacities of the various sizes of powder containers, but omitted comment on final dusting and storage of powder. Average daily output, Lammot guessed, was actually nearer 120 kegs.

Upon leaving the Dartford mills Lammot was promised 6 lbs. of the

best sporting powder to bring home. He appreciated his host's openness and politeness and assured Mr. Wilks that if he or any member of the firm ever came to the U.S. it would be a pleasure to show them through the Du Pont mills.

Next on his itinerary were the Roslin Mills of Hay, Merrick & Co., about six miles from Edinburgh. By pure chance on the train from London to Scotland he got into conversation with a man who turned out to be a machinist who had recently made six pairs of rolling wheels for the Waltham Abbey Mills, the government mills Lammot was most anxious to visit. The machinist promised to send him plans of some new rolling mills soon to be erected in South Wales. These must have been described in considerable detail for Lammot vowed that "if he does not send me the drawing, I will draw it from his description."

It is not the writer's intent to burden readers with detailed and largely repetitious descriptions of the other mills Lammot visited during the remainder of his stay in Europe. Pigou and Wilks has been described at length because it was the first he visited, and because his account of it gives the reader a general knowledge of how black powder was made. The sketches he made of the general plan of the factory and the well-executed drawings of floor plans, machinery and vehicles are the best that have survived.

As we move with him through the other mills it will be primarily to observe the aspects of processes and machinery that differed from those with which he was familiar; those that in his opinion were not as advanced as Du Pont methods; and others that appeared to him worth learning more about with a view to adopting. Sometimes the latter possibility is implied rather than directly stated; in such instances the writer will

draw upon his knowledge of the workings of the Du Pont mills at that time to infer what was probably so obvious to Lammot that noting it seemed superfluous. When he returned home his journal would be his "aide-mémoire" for discussions with Uncle Henry and other members of the firm.

At the Roslin Mills one of the owners, Mr. Merrick, was Lammot's guide. The first buildings had been erected in 1803, with newer works added in 1820 and again in 1854. In the refinery Lammot was surprised to see the clarified liquid saltpeter drained through sixteen thicknesses of flannel to further purify it before it crystallized. A vertical éprouvette for testing the strength of powder caught his eye in a millwright's shop; this he sketched in the margin of his journal.

Sulphur was carefully refined by the method familiar to him, and he noted that what was rejected was sold to vitriol manufacturers at £ 4 a ton. For the best sporting powder sulphur was remelted and refined a second time; a sample of this, with a sample of their saltpeter, was given to Lammot.

At Roslin the three ingredients were given a preliminary mixing under light-weight rolling wheels, but were rolled dry, no water added, a dangerous procedure in Lammot's judgment. All the rolling mills were built of heavy cut stone, the machinery was well made, and the gearing in most of them was under the mill floor, features he thought superior to the Dartford Mills. At Roslin the powder under the wheels was watered by hand, not from a suspended bag seeping water onto it. The wheels trundled around at 8 r.p.m., and the operator let them run until the mix began to throw off a light dust, a hazardous technique but one which had become standard practice here.

One mill contained the three different machines needed for pressing, granulating, and glazing. A modern hydraulic press powered by a pump was used in place of the older mechanical turnscrew type Lammot had seen at Dartford. Layboards were of copper instead of wood, and again, as at Pigou and Wilks, no damp cloths covered the layboards. Mr. Merrick admitted that glazing powder gave it an attractive glossy sheen, but he would not coat his powder. Lammot records no reason for Merrick's objection, but not all powdermakers accepted the claim that glazing resisted dampness, and some believed it slowed down the speed of combustion.

Roslin's dry house was an octagon-shaped building with a stove in the middle. Built into the walls were frames holding racks covered with canvas on which the powder was spread to dry. About 300 yards distant was the proving ground where a mortar that fired a 68-pound cannon ball was used to test the strength of cannon powder; a charge of 2 ounces of powder was expected to hurl the ball a minimum of 250 feet.

Passing near stored piles of wood awaiting charring Lammot was told it was English dogwood from which all knots had been bored out, and each piece had been carefully washed and wiped by women workers. He was given a sample to bring home.

Roslin made its own barrels and kegs in sizes ranging from 100 lbs. to 5 lbs., and it also packed powder in 1 lb. and 1/2 lb. tin canisters. The hoops around the barrels and kegs were of various kinds of wood, not giving a neat, uniform appearance to Lammot's eyes; and, most surprising, to open a keg the head had to be knocked in for there was no bung hole in either the bilge or the head from which to pour the powder.

The powder market was talked about as Lammot was about to take

his leave. Mr. Merrick informed him that the price of blasting powder in 25-lb. kegs had recently been reduced two shillings, "and the agreed price for March, April and May was 54 shillings /$3.26 1/2/." The "agreed price" implies that English powdermakers were informally fixing prices of their product in 1858.

From Roslin Lammot rode to Glasgow, and early the following morning took a boat to Ilsen on the Isle of Bute to visit the Kames Powder Company. This company was a partnership established in 1831. The managing partner, a Mr. McCullum, lived near the mills, the other partners residing in Glasgow, Liverpool, and London. Mr. McCullum happened to be in Glasgow that day but his son Duncan agreed to take Lammot through the mills. For a long time Kames had made only blasting powder, but recently had been producing sporting and government powder, and it had become the third largest producer of sporting powder in the British Isles, probably in the world, according to his young guide. Lammot fails to note whether he was tempted to make a rejoinder.

The entire plant, including the director's and twenty workmen's homes, was surrounded by a seven-foot stone wall; at the Du Pont plant, only the mill area had a seven-foot board fence around it. More familiar in appearance to Lammot were the mills built with three thick stone walls, a frame fourth wall, with roofs of thin corrugated iron laid on but not fastened. Both water power and steam power were used to drive them and all their gearing was encased in wood, a feature Lammot had never seen, but possibly a necessary protection against the cold Scottish winters. Some mills had floors of rammed earth, others had yellow pine flooring. Little else appeared novel to Lammot except that Kames had no charcoal houses for it bought its charcoal in Glasgow. Young

McCullum gave the visitor a pound of the best quality musket powder made for the government which Lammot thought was flinty, coarse, badly glazed, and the grains too large, about the size of Du Pont ordnance powder.

Another visitor at the mills, who returned to Glasgow with Lammot, was a Daniel King of the Camlachie Chemical Works in that city. Lammot accepted his invitation to visit his plant where 3 tons of wood, mostly oak, were made daily into charcoal. From a ton of wood King stated 150 to 180 gallons of pyroligneous acid could be obtained along with 10 gallons of naphtha. The naphtha was sold to varnish makers and the acid was used to make iron liquor. Camlachie sold its charcoal to iron foundries and also supplied the Kames Powder Co. Inadvertently King revealed it was not pure charcoal, but "consolidated" charcoal, half charcoal and half coke. Kames preferred it to 100 percent wood charcoal because it incorporated better with the sulphur and saltpeter under the rolling wheels. Lammot was sworn not to disclose this manufacturing secret.

The train ride from Glasgow to London the next day provoked some mixed observations on British railroads and railway cars. Good roadbeds made smooth riding; tracks were straighter and the banks better landscaped than in America. Pleasing to the eye were the narrow garden patches paralleling the tracks cultivated by local railway employees. But the railway carriages:

> If my <u>amor patriae</u> does not blind my judgment entirely I think we are infinitely ahead of them. First, their carriages as compared to our cars - they each contain 18 persons, 6 in each compartment. Now if you have pleasant company, well enough, but 1,000 to 1 there is not a word spoken by anyone, whereas in ours you look around and find some one you know and can have a pleasant chat, but here your sweet-

> heart might be sitting within 1 inch of you and you not know it. Half of the passengers have to ride backwards so there is a rush for certain seats as some people are made sick by it. In long journeys your legs get cramped as there is not room to stretch them if any person sits opposite you. But fortunately no one takes long journeys in England.

Lammot, a moderately gregarious man, was over six feet tall - both his temperament and body structure were cramped by British rail car technology. Seats were hard, straight, and uncomfortable, even in first class in which he was riding in mid-March. Pans of hot water were put in the bottom of the first class cars, but not in the second and third class. The two latter were more like American cattle cars, open sides and narrow benches, deliberately made so, in Lammot's opinion, to force people to ride first class. Then his sense of class consciousness led him to note that it would not be good to have all one class - the undesirables, drunks, and common people-riding with people of class and respectability.

Woolwich Arsenal was not open to visits by powdermakers from abroad, but Lammot felt he must get in to learn what he could about recent developments in British ordnance. On March 15 he called at the U.S. ministry in London seeking the assistance of George M. Dallas, U.S. minister to Great Britain. The secretary of the legation, Benjamin Moran, greeted his fellow American and subsequently penned this brief description of him:

> Lammot du Pont of Delaware, one of the powder family, called to see us for a pass to Woolwich, but we could not give it. He is a tall young fellow wearing spectacles, walks clumsily, but talks well and is gentlemanly.[18]

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[18] The Journal of Benjamin Moran, 2 vols., edited by S. A. Wallace and F. E. Gillespie, V. 1, p. 266.

No mention is made of Lammot with the customary cigar in his mouth, nor of the shawl around his shoulders, a usual part of his attire. Dallas had had three identical requests in the past three months and had been refused passes in every instance; it had become a sore point with him. If Lammot insisted he would try again, but he should not expect an answer within ten days. Lammot said he would try other channels.

While waiting for responses from several persons who might obtain him admission to Woolwich he went to the British patent office to see what patents on explosives had recently been filed. For a shilling each he could buy a copy of any patent, with specifications and drawings, and accordingly ordered all the newer ones on the subject of gunpowder, an expenditure of twenty shillings. Some might be of no use, "...yet there are some curious ideas patented." Money was also deposited to pay for four new patents that had been filed but for which copies were not yet available; these he ordered sent to him in the United States.

Late that same week, after being rebuffed twice, he got into Woolwich, but only after being "cross questioned as to my pedigree. I had entered my address as Morley's Hotel, but I confessed I was a Barbarian from the States, and was escorted by a Bumaladdy to Cap't. Boxer's office." Happily, the captain proved an affable person. He informed Lammot that Du Pont's was the only foreign powder that gave satisfaction at Woolwich. Another officer who joined them commented that Du Pont's musket powder was as good as the English, but there was so much prejudice against foreign powders it had been used to fill shells.

Lammot was amazed by the bustling activity and the size of Woolwich. The grounds extended over 5 miles, and 22 vessels were loading and unloading simultaneously at the wharves. There were tremendous

stores of ammunition and weapons; in one long row he saw 600 8-inch mortars. He also saw "the shot for the celebrated 3-foot mortar which with a charge of 180 lbs. /?/ of powder was to throw 5 miles. The shells weighed from 26 cwt. to 27 cwt., but with 40 lbs. of powder at 45° angle she threw 100 yards only and broke her fastenings. The shells penetrated 16 feet in the marsh... they say she is a failure." He may have wondered if this had been England's secret weapon planned for use against the Russians in the Crimean War.

Time was found for some sightseeing in London. He went to Sydenham Palace where some of the exhibits that had been in the Crystal Palace Exposition of 1851 were now on display. The handsome building was more impressive than its contents to the visiting powdermaker:

> The machine department contains nothing worth seeing except a gold crusher & a couple of steam engines; all the rest are washing machines, etc., etc., Yankee notions put there as advertisements.

A boat ride on the Thames took Lammot from Westminster Bridge to London Bridge, and from here he went to the Fire Monument, counting the 311 steps to its summit. The vista he had contemplated was blotted out, "London was too smoky to see anything." In the Tower of London he saw the collection of antique weapons and armor and the crown jewels. At the docks he looked with special interest at the Leviathan, a steam paddle-wheeler designed to cross the Atlantic in six days. Lammot confided to his journal this was impossible; the paddles were too narrow and the screw had insufficient pitch - "the screw ought to be about double the pitch, or about 40 ft. instead of 22 ft." His visit to Greenwich Observatory was time wasted for he could not get in.

The Maresfield Powder Works near Lewes in Sussex was next on his itinerary. Henry E. Drayson, the English powdermaker who had visited the Du Pont mills the previous November, had stated he was part owner of

the Maresfield works. But he was not on hand to greet Lammot, an absence quickly explained by another part owner, the superintendent of the plant, Frederick G. Spray. Drayson, he told Lammot, had spent time in prison for forgery and other misdemeanors, and was no longer connected with the business. Lammot wrote him off as a "Damn rascal!" - his strongest epithet, in writing.

Boiling the three ingredients of powder in a vacuum pan, a process patented by the Maresfield Company, was explained to him in detail. A new building was under construction to house it. He was impressed by the results of the comparative firing tests the superintendent made for him on the éprouvette, firing a 68-lb. ball with 2 ounces of powder. Du Pont's superfine Eagle powder hurled the ball 430 feet, but the new Maresfield powder topped this by well over 200 feet, the ball going 662 feet. Other powders, all English, threw it varying distances from 320 feet to 450 feet. The Maresfield powder was also the cleanest, leaving the least residue in the gun; Du Pont's was second, but it made the most noise. The vacuum pan process was sketched and described very precisely by Lammot, to which he appended some questions about the greater yield of pure saltpeter claimed by its inventor. Four years earlier he had experimented with a slightly different vacuum process and had discarded it as uneconomical.

Maresfield had a glazing barrel that was an improvement over the usual type. This consisted of a smaller barrel with 6-inch wooden tines, or pegs, projecting from its exterior that revolved within a larger barrel; the inner barrel turned at 50 r.p.m. and the outer 25 r.p.m. Mr. Spray contended this cut glazing time by two-thirds, from six hours to two hours, without affecting quality. Lammot grew cautious when the

superintendent stated that if the Du Pont Company wanted to purchase the American rights to the process, all negotiations should be with him personally, not the company. "This looks bad," he noted in his journal. A complete tour of the mills was not offered by his host, but he was given several samples of Maresfield powder.

Upon returning to London Lammot took steps to have his passport visaed for crossing to France; he had heard that delays were commonplace. The waiting time was not wasted, for opportunely he received a letter of introduction from Captain Boxer at Woolwich that would get him into the Waltham Abbey Mills. Here he would be less a stranger for he had prepared himself by reading the memorandum his Uncle James Bidermann had written when he visited the mills in 1838.[19]

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[19] Memorandum on Waltham Abbey Mills, James A. Bidermann /~1838~/, Acc. 384, Series B, EMHL.

It turned out to be less than the full tour Lammot had anticipated. Major J. Fraser Baddeley, the superintendent, was willing to show him some new rolling mills and others under construction, but the major said he did not have the authority to take him into other parts of the extensive works; Lammot would first have to secure permission from the Ordnance Board in London, a disappointing delay. However, he did jot down descriptions of the rolling mills, all driven by a double cylindered, high pressure steam engine powering a single shaft that passed through an arch beneath the floor of each mill. The roll wheels were a "light" 5-1/2 tons each, 6 feet in diameter, and with a face 17-1/8 inches. Lammot made special note of the safety devices in these mills which consisted of "an arrangement so that when one mill of the set blows up it loosens a catch

and upsets about 3 cubic feet of water on the platform of each of the mills that did not blow." The mills resembled Du Pont's in design and material, but the walls were only 13 inches thick.

A well-equipped shop with many tools and machines to construct and repair all types of powder mill equipment was interesting to him, particularly a horizontal boring mill capable of turning the large iron rolling wheels and bed plates of the rolling mills. Whether he realized the wisdom - the economy, control, and time saved - in having such a facility readily available in the Brandywine Mills we have no direct knowledge, but in July 1858, two months after he had returned home, a machine shop 100 feet long and 30 feet wide was under construction in Du Pont's Hagley Yard.[20]

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[20] Delaware Gazette, July 13, 1858.

At the office of the Ordnance Board in London he learned it would take a week to act upon his request to see the rest of Waltham Abbey, a wait that decided him to cross over to France. His frustration at English business practices led him to remark, "The London days are very short, nothing done before 10 and nothing after 4 o'clock in the afternoon." To this he added a complaint about expenses, "Traveling in England costs something, say $15 per day. If you look at a man he will ask you for a shilling, and nothing is free."

Bureaucracy, Lammot soon found out, was synonymous with delay and red tape, whether it be British or French. At Calais the powder samples in his baggage caused a contretemps with the customs officials. Lammot had declared them, and his cigars, but was incensed at the liberties they took with his other baggage. Briefly it looked as if the gendarmes would

haul him up before a magistrate. The matter was unexpectedly resolved when the exasperated customs officer jammed everything back into Lammot's bag with the declaration he would charge him nothing!

More delays beset him in Paris where he learned that his request to visit the French powder mills would take three days for a response. Rather than wait around he decided to go to Wetteren to see a Belgian powder mill. To his consternation he found that "My passport must be visaed by the Belgian consul, the Dutch, the Prussian, as well as by the American minister and the Prefect of Police, who closes his door at 2 o'clock." The wait afforded him opportunity to tour Paris - the tomb of Napoleon, the Assyrian and Egyptian museums, the Place Vendôme, the Arc de Triomphe, the Library of the National Institute, the Bastille monument, the Artesian Well of Grenelle, and the Louvre, where he hurried "through the galleries of paintings."

He also went to the shop of M. Bianchai, a "great apparatus man," and ordered a "Densimètre à Mercure," of which "there is not one in our country." From what source he does not reveal, but he obtained drawings of a new type of glazing barrel being made for the Turkish government. Some features of it resembled those of a barrel his elder brother Eleuthère Irénée du Pont II had made a few years before. Copies of recent experiments on drying powder in a vacuum were ordered, and he tried to buy some powder but could not do so without a permit.

Lammot arrived at Wetteren on Friday, March 30. Mr. Charles Van Cromphaut, director of the Royal Powder Mill eight miles from Ghent, was "a very gentlemanly Dutchman," Lammot wrote, "who could not speak one word of English, but French, so I had to jabber away with such success that he finally showed me his mills." Surprising amenities were

encountered; above the director's office and laboratory was a recreation room with a billiard table and stocked sideboard, presumably for the accommodation of government ordnance officers whose duties brought them to Wetteren. Since the mills were erected in 1760 there had been only two explosions, one man killed in a rolling mill, and one killed "by some powder taken from the French at Waterloo in 1815," a remarkable safety record for nearly a century of operations.

Refining was done as in the Du Pont mills, the same process, with a few minor variations, as set forth in Botteé and Riffault's work of 1811. Lammot noted, possibly with some surprise, seeing women pushing wheelbarrows loaded with crude saltpeter from the storehouse to the refinery. At the Du Pont mills women peeled willows, punched holes in sieves, cut and pasted labels on canisters, and, if necessary, the wives and children of the proprietors helped with the labeling. Wetteren's 16 rolling mills were built of wood, some driven by steam turning 7 r.p.m., others utilizing horse power turning at 4 to 6 r.p.m.

For drying powder Van Cromphaut had installed in his dry house a number of canvas bottomed tables, 4'6" x 10', each holding a 3-inch layer of powder which was dried in about 2-1/2 hours by a stream of air blown against the underside of the tables. This new technique which replaced steam and hot air dry houses, or dry tables in the sun, dried it faster than these usual methods.

Glazing the powder for a time in small barrels before putting it into larger barrels, the director assured Lammot, kept the grains from breaking down into dust, a chronic problem in the glazing operation. Wetteren was the only mill Lammot had seen thus far in which wet cloths were spread over the lay boards in the pressing operation. Sporting

powder, production about 500 lbs. a day, was made as Du Pont made it, and production of blasting powder was 8,800 lbs. a day. Powder was tested on a ballistic rifle éprouvette and on a 68-lb. éprouvette mortar. About 180 employees worked in the plant.

Mr. Cromphaut impressed Lammot as a generous, thoughtful host, very polite, and on departing he invited him to call at the Du Pont mills if he ever came to the United States.

From Wetteren Lammot went to Brussels to spend the night, and the next day traveled to Spandau, some miles west of Berlin. He found Major Otto, the director of the mills, to whom he presented his letter of introduction from Captain Mordecai of the U.S. Ordnance Bureau. It was a holiday so the mills were not working, but Major Otto escorted him through the works, and Lammot saw some advantage in examining equipment while stationary.

All the mills at Spandau were at least 220 feet apart, "much farther than ours," built of brick with slate roofs, and set within earth embankments reaching as high as the eaves of the mill. Ingrain carpet covered the mill floor, and where the workmen customarily walked sheep hides were laid on top of the carpet. The grounds were neatly laid out, characteristic of "all government works," the mills being connected by tanbark paths. There had not been an explosion in twenty-one years.

The refining process was familiar, but Lammot saw fit to note that the "refuse," or unwanted salts, were said to contain 35% nitre. Such a high percentage implied the method was wasteful unless the discarded salts were sold to processors who could extract various chemicals from them. The refinery's daily capacity was enough saltpeter to make 4,000 kilos of powder, working only daylight hours. Major Otto was surprised to

hear that the Du Pont plant operated day and night.

Wood for charcoal (Lammot could not learn what kinds for they were named only in German) was aged six years before being charred. Charring was done in retorts 6 feet long and 27 inches diameter, peat being the fuel in the furnaces because coal and coke generated a high heat that burned out the retorts. An elaborate system of pipes tapped off the gases, the pyroligneous acid and the tar.

Powdercake from the rolling mills was put through an ingenious system of rollers to harden it preliminary to being placed in a hydraulic press. Water (20%) was added as it was being pressed, otherwise it would not granulate well nor take on a good glaze. Before granulating, the powder was air dried in the largest dryhouse Lammot had ever seen, a structure 180 feet long and 35 feet wide. It was dried a second time after being granulated, and then glazed by steam in copper barrels. After glazing it should contain only 1 1/4% moisture and need not be dried again. This was a departure from general practice, but in Major Otto's opinion the good effects of glazing were lost if powder was dried again, because glazing closed the pores of the grains and drying opened them. He had tested powder made both ways, and that made without a final drying had proved superior, but the Prussian government "would not change as they do not like changes in Prussia." Separating powder dust from the grains before packing was done by a complex arrangement of bags, a procedure Lammot had not seen elsewhere.

On leaving, Lammot was given samples of a number of types of powder, Major Otto confiding to his visitor that he would be dismissed from the army if it became known he had done so. Lammot pledged silence and promised to send him samples of Du Pont powder through the American consul.

Train travel on the Continent was no better than Lammot had experienced in England; it took two days and two nights to get from Spandau back to Paris. At Gare du Nord all of his powder samples were seized by customs agents despite his heated arguments and efforts to bribe and "bluff" them. Writing to his mother (a copy of the letter is in his journal), he prefaced an account of this episode by telling her:

> I filled my pockets full but found that if I tried to smuggle all that I would cut such a figure they would examine my person, and I would lose all, so I put 5 lbs. in my pockets and concluded to chance the rest. The first thing they found was a pistol with singular arrangements /a pistol éprouvette?/ and plenty of powder and brass balls.

Determined not to return to the U.S. without the powder samples, he appealed to higher ranking customs officials, to a magistrate, the commissioner of police, and finally was referred to the minister of war, said to be the last resort in such matters. But first he addressed a petition to the chief of the customs service in which he explained his role as an American powdermaker who, having recently suffered heavy losses in a serious explosion (that which had killed his Uncle Alexis the previous August), had come to Europe to examine mills and processes to guide him in rebuilding "on the most approved plans." The samples of powder taken from him were important for they would be analyzed and compared with Du Pont powders. He would be sailing from England to America on April 28, and he would welcome "the clemency which my case deserves."

Impatient, he called upon John Y. Mason, U.S. Minister to France, seeking his intervention. Mason accompanied him to the French War Office to call upon Maréchal Vailliant, Minister of War, but that gentleman being not available, Mason left a note describing du Pont's plight, with the request that Vailliant intercede to have the samples returned to him. Lammot's journal implies that some douceurs would have to be paid before

he would get them back. He was already overdrawn on his French letter of credit, but when he returned to London on April 19 he sent Mason £ 100, "which I hope will be readily disposed of in Paris ... hoping it will answer every purpose." Mason acknowledged it, but considered it a personal loan - he was short of funds - and he promised to pay 6% interest on the loan. Mason died in 1859, heavily in debt, and Lammot's efforts to collect from his heirs in 1860 appear to have been unsuccessful.[21]

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[21] Acc. 384, Series B, EMHL.

While waiting for action on his petitions to have the samples returned, Lammot visited the government's saltpeter refinery in Paris where he was shown about by M. Maurau, the director. Instead of Calcutta saltpeter, potassium nitrate, the French were now using sodium nitrate produced locally and from Prussia, but with poor results. Maurau inquired if Du Pont had ever used sodium nitrate, and with what results - "In fact he pumped me, or tried to do so, but I kept quiet." For what reason we do not know, but Lammot did not tell Maurau of his own recently patented process (see note #10) for using sodium nitrate in making blasting powder.

In general layout and procedure the Paris refinery resembled the Du Pont refinery, Lammot noting that the former was using coal to fuel its furnaces, "as wood got too expensive." The Paris refinery supplied saltpeter to some of the government mills; refineries in Marseilles, Nancy, Lille and Bordeaux supplied the others. Lammot made a list of the government mills, some of which he would visit:

Angoulême	St. Chamas
Le Bouchet	St. Medard
Esquerdes	St. Ponce
Metz	Pont de Buis
Ripault	Toulouse
	Vonges

Between April 13 and 19 he found time to visit the mills at Le Bouchet in Seine-et-Oise, Ripault near Tours, and Esquerdes near St. Omer, to which he had been issued the necessary passes by the Ministry of War office. The captain in charge at Le Bouchet was initially cool to the visitor, but Lammot seems to have had a knack for breaking down reserve; he customarily had with him a supply of good cigars; not, however, to be smoked in the immediate vicinity of the mills.

A few things caught his eye that differed from the familiar: sulphur and charcoal were pulverized in dust barrels, two feet greater in diameter than those used by Du Pont, by balls of gunmetal that tumbled among the ingredients and crushed them. One of the gunmetal balls was given him to take home as a sample. Stamping, or pounding, mills, an older method of mixing the ingredients which Du Pont had discontinued in 1837, were still being used at Le Bouchet; ten were in operation making cannon powder, while only two rolling mills were making sporting powder. Ever alert to word of new processes, Lammot learned that a private company was about to make saltpeter by a different method. Nitric acid was to be taken from the air and potash derived from evaporating sea water, after which the salts of potash would be separated from the soda salts. This venture was being capitalized at four million francs and one of the promoters was reputed to be the emperor, Napoleon III, investing through a General Brissole.

A slow (15 1/2 miles an hour, he calculated) train took Lammot to Tours, the nearest city to the mills at Ripault. There was compensation, however, in the enjoyment of the beauty of the country through which he rode, "the garden of France, ... it is a most beautiful country," he wrote of Touraine. We do not know if Lammot was aware of it,

but in 1802 his grandfather had sent seeds and tree cuttings from America to France. The recipient of some of these, M. Riffault, official in the Régie des Poudres and co-author of the book on powdermaking, Traité de l'art de fabriquer la poudre à canon, 1811, who had a small estate in Touraine, had acknowledged the gift from E. I. du Pont in these words:

> It is much to be wished that our beautiful Touraine, already so rich in fruit trees, should become so in thriving nurseries of ornamental and useful trees. I think that most of the superb American ones will thrive. And you would surely deserve much of your fatherland if you contributed so wisely to the improving and beautifying of one of the most beautiful parts of her territory. [22]

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[22] E. I. du Pont, Botaniste: The Beginning of a Tradition, by Norman B. Wilkinson. The University Press of Virginia, 1972, pp. 23, 26.

The Ripault mills were much like those at Le Bouchet, and the refinery similar to that in Paris. Their capacity was 4,000 kilograms of powder daily, but Lammot estimated that actual production was about half that amount.

The Esquerdes mills, six miles from St. Omer, which his Uncle James Bidermann had visited back in 1838, were the last on Lammot's Continental itinerary. A steam process for charring wood interested him most at this establishment. It was claimed to be an improvement over the Violette process, one he knew well. It was difficult to divert the superintendent of the plant from this subject for he had recently been issued the patent for the new method and he appreciated an attentive ear. Lammot noted, "The plan of a steam coal house to be built at Esquerdes which we have was never built."

In the packing house he saw that the best quality powder was being packed in attractive varnished (Japanned) tin canisters holding a quarter kilogram. His request for a few samples was refused; the request

would have to originate with the U.S. Minister to France and proceed through official channels, which moved Lammot to sarcasm: "The French officers are afraid of their shadows." His calculation of production in the government mills was that they produced only half the amount of powder of which they were capable.

Lammot was back in London by Sunday, April 19, and the next day went to Sheffield to call upon Dixson and Sons, a metal processing firm, seeking a supply of metal canister stoppers and powder flasks. But Dixson's policy was to stamp its name on everything it made, and its prices were too high. In the factory about 300 persons worked on plated ware and large quantities of powder flasks, one of the better American customers being "Colonel" Samuel Colt to whom they sold pistol flasks. Dixson suggested that Lammot try some metal firms in Birmingham where he was sure stoppers and flasks of lesser quality could be obtained at much cheaper prices - "Brummagem" ware.

Instead of going to Birmingham Lammot crossed over to Ireland, and on April 22 was in Cork looking up a Mr. Henry Unkles whom he had earlier met in London. Unkles, a partner in the Ballincollig Powder Mills on the River Lee across from Inniscarra, had promised to take Lammot through them at some future time. These were new mills, erected during the Crimean War by the government but leased to private operators, and were reputed to "have the best machinery in the World." Mr. Unkles could not be found, but Lammot rode the six miles to the mills, only to be refused admission. Mr. Tobin, the superintendent, was willing to talk about operations and to show the mills to Lammot from the outside.

Ballincollig produced mostly blasting powder for which there was such a heavy demand that it operated day and night. Its power came from the River Lee, which had about half the flow of the Brandywine, and it

turned huge stone incorporating wheels 7 feet in diameter, each weighing 20,000 lbs. These were the largest rolling wheels Lammot had ever heard of. Wheels of similar massive size were installed at the Du Pont Company's Wapwallopen Mills in Pennsylvania by Lammot soon after his return from Europe. The mills in which they were installed were named the "elephant" mills. At Ballincollig the materials were moved on the raceways by boat from mill to mill. Fifty-five coopers were employed making barrels and kegs, and the finished powder was hauled from the mills in wagons, each holding 200 kegs of 25 lbs. each. His comment on the Ballincollig kegs that "Their kegs are smaller than ours but they put in full weight" is subject to differing interpretations. The first suggests that Du Pont gave short weight in its packing; the second, that Du Pont made its kegs a little larger, with some free space to allow the powder to tumble about in the kegs when they were periodically rolled to prevent caking while in storage.

Mr. Tobin gave Lammot a sample of a new kind of powder which he described as "a kind of sawdust," said to act very well at times, at other times very badly. It had been developed in France, but Mr. Tobin had no other particulars about it. Lammot noted he would look into this, "for from its appearance it might be made cheap enough to supersede /black/ powder."

Upon his return to London word awaited him from Mason, U.S. Minister to France, that his powder samples and other items seized by the French customs officers could be picked up, but he would have to go to Calais to recover them. This he did, arriving there at 2 a.m., minus passport and cigars, and forced to arouse six customs men who searched one storage area after another before they found the samples. Lammot was

amused at their refusal to let him put the samples in his carpet bag and make his own way back to the steamer; they insisted upon escorting him, with two agents carrying the powder items to make sure they were put on board.

The time was drawing near for his return home and he had not yet succeeded in seeing those parts of the Waltham Abbey Mills that had been off limits on his earlier visit. On April 27 he wrote to George M. Dallas, U.S. Minister to Great Britain, boldly stating it was his obligation to assist an American manufacturer whose product was so important to American security:

> As you are probably aware I am engaged in one of the principal powder factories in our country and have been on a tour to examine in what respects we are behind the European nations. I have been through the most important private works of England and Europe which manufacture principally for commerce. But I am very anxious to see the government mills of England where they manufacture nothing but cannon powder .... As we are the principal contractors for our government I think there can be no objections to requesting a permit as it is the duty of our government to aid rather than discourage our manufacturers in endeavoring to gain knowledge. I should have brought letters from the government to you, but I am still trusting to your appreciation of our troubles.

Not confident of the result this would bring, nor how long it would take, Lammot went to the War Department Office and filed a direct application to be admitted to the Waltham Abbey Mills. A pass was issued to him faster than expected through the good offices of Henry Byham of the War Office, and he went to Waltham on April 30.

Instead of having Major Baddeley, the superintendent, or one of the other officers as his guide - most were at the proving grounds some distance away - the foreman of the mills, who knew "nothing but the routine of the manufacture" was assigned to him. He was first shown how the raw materials were prepared and given a preliminary mixing. Saltpeter

was refined by a new process outlined in a recent aide-mémoire; and refined sulphur was refined a second time by distillation, a procedure he had not seen elsewhere. Filling the charcoal cylinders and loading them into the horizontal retorts was more speedily done by use of a rail track and friction rollers. In the press house an endless belt fed powdercake onto breaking rolls before it went into a hydraulic press to be pressed between plates of gunmetal, a material found to be more durable than wood.

He was much impressed by the granulating machine and noted that "it is decidedly the best granulating machine in England or Europe." It was also made of gunmetal, and resembled one that had been described to him by Mr. Tobin at the Ballincollig mills in Ireland. The machine had been built at the Woolwich Arsenal at a reputed cost of £ 2000, and it could granulate 8,000 lbs. of powder daily. His notes of its construction and operating features are extensive, filling two pages of the journal; it was a more complex and efficient machine than the simple granulating machine his Uncle Bidermann had seen at Waltham Abbey in 1838.

Waltham's glazing barrels were made of mahogany with riveted copper hoops; they were 5 feet long and 2 feet in diameter and could hold 270 lbs. of powder. Both before and after glazing, the powder was dusted in reels similar to Du Pont's bolting reels except that Waltham's were perfectly horizontal while Du Pont's revolved at a slight angle. Drying was done in wooden trays with canvas bottoms against which a current of air was directed, the same method used at Le Bouchet in France.

Lammot was given samples of musket and cannon powder, and of a slow-burning powder designed for use in the Enfield rifle. Waltham had recently experimented using dogwood for charcoal - willow was generally used - getting a very coarse powder, and a sample of this was given to Lammot.

As he was leaving he noticed that preparations were underway for the cutters to go out to harvest the crops of willow branches, a task performed regularly in early spring when the sap was rising, which made it easier to peel the bark from the branches.

On May 6 Lammot boarded the steamship Fulton at Southampton for New York, eager to get home. His baggage was stuffed with samples of raw materials, finished powder, canisters, pistol éprouvettes, hydrometers and thermometers (with densimeter and pyrometer ordered to be sent), patent specifications and drawings, mill and machinery sketches, miscellaneous notes, and the journal that chronicled his active and profitable visits to European powder mills. It is safe to assume that his "ransack of Europe" consisted not only of these material things but also of a mind filled with ideas to be discussed with Uncle Henry du Pont and his brother E. I. du Pont II.

A few days after Lammot arrived home his Aunt Eleuthera wrote to a cousin in France:

> In the three months he was absent, he has contrived to see more than I had ventured to hope, besides accomplishing successfully the object of his journey.[23]

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[23] Eleuthera (du Pont) Smith to Lilia Bienaymé, May 26, 1858, Acc. 521, EMHL.

Looking to Europe for technological innovation had been a common practice of early American manufacturers of many types of goods, e.g. textiles, paper, iron and steel, leather, and gunpowder, to name only a few.[16] Though politically independent the young United States in large measure continued as an "industrial apprentice" during the first factory era, circa 1790-1840, learning, imitating, and sometimes improving upon the machine technology that had been developing in western Europe since the mid-1700s.

The black powder mills that Lammot's grandfather Eleuthère Irénée du Pont had erected between 1802 and 1804 were in every respect modeled after those in France; in his opinion American powdermakers lagged fifty years or more behind the best European techniques. He had returned to France early in 1801 to study these firsthand, to consult with the heads of the Régie des Poudres, the government's powder bureau, to visit powder mills, to obtain drawings of mill structures and machinery, to purchase some equipment and leave orders for other items to be sent later, and to recruit experienced powdermen to come to America to assist him in getting his mills established.

In ensuing years his father, P. S. du Pont de Nemours, kept him supplied with treatises, memoranda, and reports dealing with powder manufacture, and with technical journals containing articles on explosives. When in 1811 he learned of an important opus, a two-volume study titled L'Art de Fabriquer la Poudre à Canon, by Bottée and Riffault, officials in the Régie des Poudres, he urged his father to send him a copy, for "its many details of the improvements made in France may be most useful to me." And though he was an Anglophobe, hoping that French aid to American industries would harm Britain's trade with the U.S.,

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[16] See "Brandywine Borrowings from European Technology," by Norman B. Wilkinson, Technology and Culture, vol. 4, no. 1, 1963.

among his papers is a lengthy bibliography of articles on gunpowder and gunnery that had appeared in the Transactions of the Royal Society of London from 1665 to 1800.

That European improvements were sometimes appropriated and patented as American inventions is evident in a letter to E. I. du Pont from one of his sales agents; referring to a patent recently obtained by a competitor, he noted that, "Mr. Rogers discovery is like many others, a European discovery brought to light here."[17]

The flow of technical information was continued through correspondence with friends and relatives in France, by the prolonged visits abroad made by du Pont's son-in-law James Bidermann in 1827-1828 and again in 1837-1839, and from discussions and reports of U.S. Ordnance Bureau officers upon their return from tours of European mills and arsenals during the 1840s. There was therefore ample precedent for Lammot's visit in 1858, and it would implement his father's dictum previously noted, that "In an establishment like this it is essential that we keep ourselves informed of whatever is new in our line."

It would be highly conjectural on our part to state what specific changes later came about in Du Pont Co. operations as a result of Lammot's survey of European mills. His journal entries and marginal sketches include much that was basically routine and familiar, some equipment or methods varying slightly, as well as features that were apparently quite different or totally new to him. His penchant for thoroughness, if at the cost of some repetition, was a strong personal characteristic, and when back home discussing the state of European powdermaking with his uncle and brother he knew they would be interested in similarities as well as differences.

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[17] Life of Eleuthère Irénéé du Pont, from Contemporary Correspondence, trans. and ed. by B.G. du Pont, (Newark, Del.: 1923-1927; 11 vols. and index), vol. 9, pp. 64-65; John Vaughan to E.I. du Pont, Dec. 3, 1818, Acc. 500, EMHL.

His matter of fact style of writing makes it difficult, with some exceptions, to determine what really impressed him, what features to his mind placed European powdermaking technology ahead of American; those, therefore, that might be beneficially adopted in the Du Pont mills. But despite his absence of emphasis and sharp contrasts, an analytical reading of the journal brings into focus a possible relationship between certain things he observed and what did take place later in Du Pont operations.

It will be recalled that one of his specific aims was to learn what Europeans had been doing in developing a dense, large grain, slow burning powder that could safely be used in the recently developed large caliber cannons. This was why he had persisted and finally gained admission to Waltham Abbey where such developmental work was being carried on with the forerunner of what later became large grain "Pebble" powder. During his four days at Waltham - the longest stay at any powder mill - it is highly likely, though his journal is vague on this, that from discussions with superintendent Major Baddeley and laboratory men, and from his own perceptive observations, he absorbed ideas that contributed to the subsequent development of Du Pont's large grain Mammoth powder. A sample of a coarse, large grain powder designed for firing the biggest mortar at Woolwich was given him upon his departure. Upon his return he renewed his collaboration with Captain Thomas J. Rodman of the U.S. Ordnance Bureau and late in 1859 they successfully test fired it in the largest caliber cannons.[18]

The prime movers in the mills that Lammot visited were waterwheels, turbines and steam engines. In his comments on these he gives the impression that despite the increased hazard they posed, greater reliance was put on steam power than in

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18 "History of Mamouth [sic] Powder," undated memorandum by Lammot du Pont, Acc. 384, EMHL; Properties of Metals for Cannon and Qualities of Cannon Powder, by Thomas J. Rodman (Boston, 1861), 217-274.

American powder mills. In the early 1850s there was only one small steam engine in all three Du Pont powder yards, but a chart prepared by Lammot in 1874 enumerated ten in operation producing an aggregate of 202 horsepower.[19] Certainly not a rapid shift in a 16-year span, but what acceleration it had might have stemmed from Lammot's observing that they did function safely and efficiently in European mills. Even in the advanced age of steam, however, one can appreciate why conservative and safety conscious powdermakers were reluctant to install furnaces that could emit sparks and boilers that could explode in close proximity to buildings containing powder. This may account for the slow pace of conversion from water to steam power.

Within a year after his return Lammot was assigned the task of rebuilding a damaged powder plant that the Du Pont Co. had bought in Pennsylvania close to the anthracite coal fields. This was the first move of the company away from the Brandywine, to a place called Wapwallopen on the Susquehanna River, about twenty miles south of Wilkes-Barre. In one pair of rolling mills, to become appropriately named the "Elephant Mills", he installed huge cast-iron edge runners of the size he had seen at Ballincollig, each seven feet in diameter and weighing ten tons. To the best of our knowledge there were none so massive in the home mills nor in any other American powder plant at that time. The conclusion seems inescapable that they were counterparts of those in the Irish mills.

Neither in these mills nor in any others of which we have knowledge were cisterns of water placed above the edge runners as dousing devices, which Lammot had made special note of at Waltham Abbey. In a collection of Du Pont Company

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[19] "A Summary of Water Wheels and Steam Engines in the Du Pont Powder Mills, 1874," by Lammot du Pont. Acc. 384, EMHL.

technical drawings one mill sketch shows tubs of water positioned above the runners, which suggests this safety device may have been considered, but no references or construction data indicate it was ever adopted.

In 1865 Lammot was granted two patents for improvements in gunpowder presses. One was for the substitution of hard, indurated rubber as the material for the layboards or plates in place of wood, leather or metal. This material apparently soon proved unsatisfactory for plant inventories of 1866 and 1867 show a stock of discarded broken rubber press boards on hand, and, for the first time, the inventories list new press boards made of gunmetal. Was this substitution of gunmetal influenced by the Waltham Abbey presses which had gunmetal press boards? We can only speculate. His second patent was for the invention of a horizontal press which could be operated either by hydraulic or steam power.[20] At several of the British mills he had seen horizontal hydraulic presses at work and had remarked upon their superiority over the older vertical screw-type press. Again, had the inventive spark been primed by his observations of 1858?

Following his death in an explosion in 1884 at the Repauno Chemical Co., which he had established in 1880 to produce high explosives, Lammot's major technical contributions to the Du Pont Co. were enumerated by Francis G. du Pont, a younger cousin and member of the firm. Included in this lengthy list are the horizontal screw press and the horizontal hydraulic press. He is also credited with improving the granulating machine by equipping it with elevators, adding levers to the rollers, and installing shaker shoes.[21] We are not certain when

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[20]U.S. Patent Nos. 50,104, September 26, 1856, and 50,568, October 24, 1865.

[21]"Explosion of the Nitro-glycerine House of the Repauno Chemical Company," LMss, Group 5, Series C, EMHL.

these granulating mill devices were adopted but it could have been between 1859 and 1865, a period when a series of explosions made necessary extensive rebuilding of mills and the replacement of machinery. One of the few superlatives found in his journal was his declaration that the granulating machine at Waltham Abbey was "...decidedly the best granulating machine in England or Europe," and, by implication, better than any in America. So we ask, were Lammot's improvements inspired by or in some respects patterned after features of the English machine - was it the prototype of a new Du Pont vertical granulating machine which we believe was put into operation during the 1860s?

If the copies of the twenty patents he had purchased at the Patent Office were still extant among his papers or in company archives they would no doubt give us some clue as to which recent powdermaking developments he thought worth further investigation, but these have not been found.

From formal training and from his laboratory experience he recognized and valued superior chemical apparatus, thus his purchase of several pieces of equipment from M. Bianchai of Paris, "a great apparatus man." One item supplied by Bianchai was a mercury densimeter, which Lammot asserted would be the first introduced into the United States. When discussing the measuring of the specific gravity of powder with Colonel Boxer at Woolwich he had learned it was done by a piece of French apparatus but Boxer would not let him see it nor name the maker. Persisting, or "pumping," as he termed it, Lammot found out from a subordinate of Boxer's that it was called Mallet's apparatus, that all the principal French powder mills used them, and that they too were made by M. Bianchai. Accordingly he placed an order for the device with M. Bianchai and it was received four months later.[22]

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22 "Memorandum on Specific Gravity," n.d., Acc. 384, Series B, EMHL.

In the posthumous listing of Lammot's technical contributions to the Du Pont Co. the compiler credits him with designing an improved specific gravity instrument and also a better gravimeter, or hydrometer.

One could speculate at length on other possible benefits that resulted from Lammot's observations, sketches, acquisitions, and conversations with his powdermaking hosts. To enlarge upon the specific instances of the suggested "borrowings" already mentioned, however, would only belabor what we believe has already been amply demonstrated as objectives attained. Whether it was from this fund of technical information he brought back from Europe enhancing his proven abilities we can only hypothesize, but within a short time of his return home all chemical and technical matters in the Du Pont mills were made his responsibility. Uncle Henry recognized his talents and relied upon his repeatedly demonstrated skills as chemist, engineer, inventor and builder.

These were rigorously tested during the War Between the States when the powder mills worked round the clock to keep the Union armies supplied despite the handicaps of unskilled labor, the breaking down of machinery, suspected sabotage, and frequent explosions. From her residence across the Brandywine Mrs. S. F. du Pont pictured for her husband, Rear Admiral S. F. du Pont, then commanding the blockade of the Confederate coastal states, the multiplicity and intensity of the tasks borne by her nephew:

> Lammot is killing himself in the refinery, working day and night.... [His] time is all engrossed with innumerable cares - for Lammot plans all new inventions, overlooks buildings, etc., etc., - indeed is the life of the business.[23]

Lammot's characteristic approach to upgrading Du Pont operations is seen in a proposal made to his partners for a series of monthly meetings - what today we

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23 Mrs. S. F. du Pont to S. F. du Pont, June 4, 1862, WMss, Group 9, EMHL.

would call "brainstorming" sessions. In an undated memorandum he suggested that one Saturday each month be scheduled to hear a paper given by a member of the firm on some new idea connected with the powder business. Illustrations and drawings should be used where appropriate and kept for future reference, and all present should take notes. At each meeting a subject should be selected for the next meeting, and assignments should be equally undertaken by all partners. Following the presentation of the paper there should be general discussion, particularly on points where there were disagreements. Any point of disagreement not resolved at the meeting should be subjected to experiment and reported on at the next meeting. Improvements agreed upon by all members should then be carried into effect without delay, all members helping where practicable. And, to preserve company and family unity, all votes on any questions must be carried unanimously.[24]

If we knew the date of his proposal for these "academic-industrial" seminars it would allow us to put it into better perspective vis-a-vis Lammot's total role in company affairs. Some sources indicate it may have been set forth in the early 1870s when Lammot and other younger members of the firm were seemingly growing dissatisfied with Uncle Henry's cautious and conservative attitudes toward change and innovation; these were depression years when every expenditure had to be carefully scrutinized. No further mention of the "think" sessions occur, and before claiming any originality on Lammot's part for attempting to introduce them, or implying he was well in advance of his contemporaries, we would need to know if such formally structured sessions were being conducted by management in other American or European manufacturing establishments during that period.

Lammot was aware that the weight of tradition in an old and successful family-owned company could inhibit the adoption of better methods and machinery.

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[24] Memorandum by Lammot du Pont, untitled and undated, Acc. 384, Series B, EMHL.

Inbreeding, relying solely on family members for leadership and new ideas was faulty policy in an era when the sciences, engineering, and business were becoming increasingly professionalized, their schools and institutes turning out competent specialists who were entering the industrial world. An engineer who applied for a position with the Du Pont Co. in 1875 received this response:

> We build all our own machinery, draw our own plans, make our own patterns and have never employed anyone to design or construct our mills and machinery, dams or races, roads, or anything else, being our own Engineers and Superintendents of all work done at our mills.[25]

Senior partner Henry du Pont most likely wrote this rejection letter stating his firm's self-sufficiency as proof that no outside help was needed.

True, and effective as this had been in the past, the rapid and diverse momentum of industrial technology, in Lammot's opinion, required new men, new blood, and fresh ideas if the Du Pont Co. was to stay in the van or even keep pace in the explosives industry. In a reflective mood he inserted this conviction in a memorandum on accidents, aware, no doubt, that it would be read by his uncle:

> We, the present proprietors, inherit in our business, all the good done by our fathers, as well as those things done badly; and with the march of improvement, one family in a business is more apt to fall behind the world than to be able to keep in the advance. For while improvements are spread far and wide, the errors and mistakes remain as permanent investments.[26]

These digressions, though seemingly irrelevant to our central interest of Lammot's 1858 visit to Europe, may enable us to sense how his "ransack of Europe" added to his competence and stature as a powdermaker. For the transmission of

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25 Notes of B. G. du Pont, LMss, Group 7, Series A, EMHL.

26 Memorandum on "Accidents," Acc. 384, EMHL.

technology is not solely "nuts and bolts" - machines, processes, tools, designs - but an awareness that change is endemic and that methods and men must adjust to them in fundamental ways. His thirty-year career in the family business is studded with efforts - some achieved, others thwarted - to advance and insure Du Pont's paramountcy by adopting the proven and most promising features of nineteenth-century chemical, engineering, construction, and materials technology, irrespective of country of origin. The reluctancy of the older regime to support some new directions he advocated, expanding into the high explosives manufacture of nitroglycerine and dynamite, led to separation and his organization in 1880 of the Repauno Chemical Co. But that is another story and a vastly different type of explosives technology that might be considered at another time. It is a wonder that illustrates once again that America learned from Europe's laboratory chemists and practical developers, i.e., Ascanio Sobrero of Italy and Alfred Nobel of Sweden, how to produce a far more powerful explosive that ended the six centuries' dominance of Roger Bacon's black powder.

No. 2 - View of gable end of refinery with slate roof and lead gutters

No. 3 - Floor plan of refinery

AA - Railway
B - Dry house for gunny bags and staves
CCC - Turntables
DD - Pots sunk in floor between rail tracks
E - Saltpeter warehouse
FF - Melting kettles
GG - Furnace room
HH - First set of coolers
II - Second set of coolers
JJ - Third set of coolers
KK - Slanted side of cooler onto which crystals are gathered
LL - Drains to catch "dirty" water
MM - Draining boxes
N - Saltpeter drying room
OOO - Draining boxes
PP - Evaporation kettles
QQ - Spout to crystallizing pans
RR - Crystallizing pans
S - Run-off drain from crystallizing pans
T - Funnel to receive "dirty" water
U - Pipe to D (general plan) where "dirty water" is reprocessed
V - Stack of furnace room

GENERAL PLAN OF POWDER MILLS
OF PIGOU AND WILKS AT DARTFORD

A - Refinery
B - Dry house to dry gunny bags and staves
C - Refinery to re-work refuse salts
D - Refinery to evaporate dirty water
E - Store house for crude saltpeter
F - Powder cart shed
G - Shed for wheelbarrows
H - Magazine
Pigou - Residence of Mr. Clarence Pigou
Wilks - Residence of Mr. Wilks
I - Charcoal roller pulverizing mill
JJ - Powder yard gates
KK - Powder yard fence
[illegible] - Gate tender's lodge
[illegible] - Rolling mills (19)
N - Sulphur pulverizing mill
O - Engine and boiler house
P - Cords of alder wood
Q - Cords of willow and English dogwood
R - Charcoal "coffee mill" pulverizer
S - Packing house
TT - Coal [charcoal burning] houses
U - Barn and stables
V - Circular sawmill
W - Press house
X - Granulating mill
Y - Glazing mill

No. 15 - Press House

A - Grooved rollers to break up powder-cake

D - Powder storage box

Not Coded - Mechanical press worked by capstan and lever

No. 11
Front end view of
charcoal cylinders

No. 12
General plan of
granulating mill

No. 13
Side view of granulating
machine

No. 14
Glazing mill with double
sets of barrels

No. 8
Plan of gearing in rolling mill

No. 9
Overhead view of rollers and platform

No. 10
Arrangement of water bag to keep powder damp

No. 4
End view of cooler or crystallizer

No. 5
End view of washing car with false bottom

No. 6
Powder cart

No. 7
Floor plan of old refinery now used to re-process "dirty" water