Discussion.

Mr. Hawksley. Mr. HAWKSLEY, Chairman, moved a vote of thanks to the Author for his interesting communication, and this resolution was carried by acclamation.

The Author. The AUTHOR said he had a few remarks to make in addition to his Paper. Since he had submitted the Paper, a design of a press for cutting large cubes of powder had reached him. It had arrived too late to be added to the list of designs, but he would have pleasure in showing it to anyone interested in the matter. He had also received a new design by the Krupp Grusonwerk for making tubular powder, dividing the operation over two rooms. He might say that his intention had been to show manufacturers in this country what had been done, all over Europe at any rate, with regard to the machinery and apparatus for the manufacture of smokeless powder. No doubt the greater part of the designs would be new to most of those interested, and they had not been easily procured. They would show manufacturers in which direction to extend their activity, and what points they should consider in the construction of such machines. There were a number of points incidental to the design of the machinery which he had not been able to touch upon. He would remind members of the classical researches of Bruley, on the alteration of nitro-cellulose in the various stages of working—how the percentage of nitrogen and the viscosity altered by the boiling, pulping, etc.—and on the influence which the material of which the machines were constructed had upon the ultimate quality of the explosive. He mentioned those points in the hope that they would be dealt with in the discussion. A further important point was the friction set up in the various parts of the machines, which influenced to a large extent both the propelling and expansive qualities of various powders. There had been a very striking example within the previous week of an explosion of a charge of smokeless powder in a powder-factory. So far as he knew that was the first charge that had exploded in a mixing-house, and perhaps the features in the construction of the machine which rendered it liable to such an accident would be elucidated during the discussion. The dies and moulds in which powders were pressed required a great deal of attention. No doubt everybody was aware that the friction on the walls of

the die varied very much with the size of the die and would therefore tend to dangerous alteration of the explosive. The Author.

Mr. W. F. REID thought the members were much indebted to Mr. Reid. Mr. Guttman for bringing before the Institution, in so concise a form, drawings of machinery which were difficult to obtain at any time, and, even if published, were often difficult to find. The smokeless-powder industry was of modern date. The Author had assigned its introduction to 1886, but probably he would have been more in accordance with historical fact if he had put it 2 years or 3 years earlier. Nevertheless, the general introduction of smokeless powder had no doubt taken place about 1886, that being the year when the French army had first adopted it. The machinery dealt with in the Paper might be divided into two classes, one for producing the raw materials, if that term might be used, and the other for working up those materials into smokeless powders. Machines of the first class were fairly well known, although some had been recently modified and improved. Among the improvements, the Author's design for centrifugals seemed to be very practical and useful, because those who had to do with nitrating knew that the fumes were extremely injurious to the workpeople, and men could not work properly under disadvantageous circumstances. Anything which tended to render that extremely disagreeable process of nitrating more healthy to the workpeople, must necessarily tend to improve the work done. With regard to the general process for making the gun-cotton, very little modification had been made of late years. The Author called it the Waltham Abbey process. It might, however, be more rightly called the Stowmarket process, the plans for the factory at Waltham Abbey had been supplied from Stowmarket, and only some slight modifications had been made in the process since. He thought, however, that it would be best to call it the Abel process after its distinguished originator, Sir Frederick Abel. With regard to the mixing of the acids which took place previous to nitration, whether of cellulose or of glycerine, the Author appeared to have found it satisfactory simply to run the sulphuric acid into the nitric acid. If that were done in bulk, he thought the mixing would not be quite perfect. He had found it possible to effect the mixing by running the sulphuric acid into the nitric acid through a number of tubes; but that did not give such a uniform mixture as was necessary during the nitration. The process still adopted in this country of nitrating the cellulose was really a clumsy one, and there was considerable room for improvement in it. He had made a great number of experiments in

Mr. Reid. that direction, but they had not been carried out on a large scale, and there were considerable difficulties in the way. Still, he thought great improvement was quite feasible, and he would particularly recommend those engineers who wished to work out something new, to devote their attention to the nitrating process. A German firm had introduced a nitrating centrifugal which had been shown by the Author. It overcame some of the difficulties of nitration, but, unfortunately, it introduced others. Recently he had visited a factory where these centrifugals had been tried and had been taken out again; so that evidently, although it was suitable in some cases, it was not so in all. With regard to chemical action on the plant during nitration, the iron was subject to great wear and tear, and although up to the present time that metal had been found the most suitable material, yet it was very soon dissolved. It was true that the strong acids did not act upon the iron to any great extent, but when they came in contact with the atmosphere they were diluted by the moisture in the atmosphere, and corrosion began. He had tried aluminium for the purpose, but he had found that the mixed acids corroded aluminium much more than nitric acid alone. He did not know whether the Author's experience had been similar. Apparently the sulphuric acid had a greater effect than the nitric acid. It would be a good thing if some material could be found which could be used in those centrifugals, because at one stage or another the centrifugal was almost indispensable with the present process. He knew of one factory where no centrifugal was used, the acid being simply pressed out. The process was only worked on a small scale, but it was quite possible that power might be economised and the cotton freed from the bulk of the acid with perfect safety in that way. He had also seen a factory where the nitration took place in the centrifugal, and the centrifugal itself was lifted out by means of a crane and was immersed in a large quantity of water. It was of great importance that the mass of nitrated cotton should be thoroughly saturated with water instantaneously; because if the quantity of cotton was large, and the water did not penetrate into every portion of it at once, heating took place, and consequently decomposition. It was necessary, therefore, that the washing should take place in a large body of water, and that the cotton should be subdivided as much as possible. With the centrifugal cage, if the quantity nitrated at once were not too large, that could very well be done. He thought it would be found in future that, on a large scale, nitrating in some way with a centrifugal or similar apparatus would prove the most economical

method. A great deal depended on the form of the cellulose used. Mr. Reid. Cotton waste, which was generally employed in England for the manufacture of nitro-cellulose, was very difficult to subdivide thoroughly. On the other hand, wood-pulp could be easily subdivided. Another difficulty arose with the latter material, in getting it out of the water afterwards; it mixed with the water, and there was considerable waste, because large quantities of water had to be used. But even the apparatus shown in Fig. 6 would hardly be satisfactory with the cotton waste in use in England. Rollers had been tried for expressing the acid, and were also satisfactory to a certain extent. The bulk of the other machinery for treating the nitro-cellulose was really derived from the paper-industry. When the manufacture had been first introduced, machinery in use in other trades had been adapted to it. The pulping-machines used for paper had been adopted, and the newer forms of paper-machinery shown by the Author were undoubtedly much more effective and suitable for the purpose than the older forms. The great difficulty was that cotton practically consisted of capillary tubes which absorbed the acid, and it was impossible to get that acid out by mere washing, or even by boiling; the cotton fibres must be subdivided. That was Abel's invention. The long fibres were subdivided, pulped into very short tubes, and then boiled, by which means the excess of acid, which was so apt to produce decomposition, was removed. It was quite possible and even probable that in the immediate future other forms of cellulose would be used, which would be a great advantage to the manufacturer of nitro-cellulose, as he would not have to subdivide the material to the extent necessary at present. One machine used in paper-making—a knoter—had been introduced. If the pulper did its work thoroughly, and there was perfect circulation, he thought it would be, in most cases, a rather unnecessary complication of the machinery of an explosives factory to introduce it. However, the Author did not seem to lay much stress on that particular machine. With regard to the nitration of glycerine, modern practice seemed to be in favour of nitrating much larger quantities of glycerine at one time; 5 cwt. or 6 cwt. was a very usual charge. He had nitrated more than a ton daily without any difficulty whatever. It must be remembered that subdivision did not diminish the danger but rather augmented it by increasing the number of possible sources; and, on the other hand, when nitro-glycerine exploded it mattered little to persons near whether the quantity was half a cwt. or half a ton. With reference to the apparatus, two points had to be kept in view. It

Mr Reid. was necessary to have the means of thoroughly cooling the whole contents of the vessel, and those contents must be kept in agitation during the process of nitration. There was one machine mentioned in the Paper which he was sorry to see there, viz., the mechanical stirrer shown in Fig. 12. It was a very old form, and he had been acquainted with it for a good many years, but he did not like the principle involved in it. A complete mixing of the contents of the vessel could be secured by the use of compressed air, and that method was absolutely safe; the addition of the mechanical stirrer was rather a useless complication. He had never known any accident to occur through agitation by means of compressed air, a method which had been in use for many years. He thought it would be better to get rid of mechanical action in a nitrating-house for nitro-glycerine. The first smokeless powder had been made with gun-cotton, either alone or in combination with other oxidising substances. The first made on modern principles had been "E.C." powder, manufactured in 1882. When he had first introduced the manufacture of that powder, there had been absolutely no suitable machinery in existence; everything had had to be designed specially. The Author had not described any machinery, although he had referred to it briefly, for the manufacture of granulated powders of that kind, which Mr. Reid thought had a great future. Although cordite had been introduced into this country very successfully, and also ballistite and other forms of string-like, or rope-like, powders, yet they entailed certain difficulties, and rather complicated machinery was required for handling them, and for charging cartridges with them. Powder in a globular form could be handled and measured with ease, and the loading of cartridges was therefore much facilitated. In order to be complete, he thought machinery for the manufacture of smokeless powder should comprise apparatus for producing powders in a globular or granular form. There were two large factories in this country which made such powders, and although they were not used for military purposes there was no reason why they should not be so used. It was one of the national arrangements that a certain thing was introduced and used by the Government and other things were not, but still it was quite possible that those powders might in the future become more important than the cordite form; and therefore a description of the machinery for making them would be very valuable. In the manufacture of "E.C." powder—used chiefly for sporting purposes—potassium nitrate and barium nitrate were mixed with the gun-cotton in order to obtain more rapid ignition.

The first operation was to form that mixture into grains. It was first incorporated in the ordinary way, being thoroughly mixed in the incorporating mill, and was then granulated. It was then passed through sieves, and the very rough grains produced in sieves were put into a rotary drum. That was the chief difficulty he had met with in introducing smokeless powders. The drum which had formerly been in use for granulating gun-cotton would not make a good grain. After a great many experiments he had found the cause of that to be the inner surface of the drum, and the alteration of that surface enabled an excellent and thoroughly reliable grain to be produced. He had lined the inside of the drum with linoleum, the surface of which just gave sufficient friction to cause the particles to agglomerate into a globular form. That process was much superior to vibrating sieves or trays, which, as the Author stated were in use in a number of factories. Possibly they were in use because the other method was not so well known. He had not published it, and did not think it had been published anywhere. There were other powders made in a somewhat similar way, but that had been the original process. The next operation was the drying of the grains. They were roughly sifted to get an approximate evenness of grain, and were then dried until the moisture was reduced to 1 per cent., after which the gelatinization process took place. The essential feature of all modern smokeless powders was the treatment of the nitro-cellulose, whether in its soluble or insoluble form, with a solvent which partially dissolved it; and by means of this solution the particles of the grain were cemented together. According to the strength of the solvent a hard grain like sand or a soft grain that crumbled in the fingers could be produced as desired, and consequently any velocity of ignition could be obtained. The next process was the removal of the solvent introduced to agglutinate or cement the particles, an operation which was of the greatest importance. Although the Author had rightly said that there were places where the solvent was recovered to some extent, yet the bulk of it was wasted. The solvent generally used for smokeless powders in England was acetone, and the price of that material had been doubled by the war in South Africa. If the country were engaged in a great national struggle it would be dependent on foreigners for a supply of acetone, as very little of that important raw material was made in England. It was not beyond British chemical science to make it from British materials if necessary, but as a matter of fact it would take some time to do it, and the country might be

Mr. Reid.

Mr. Reid. placed at a very great disadvantage if engaged in a struggle with one of the great European nations. Therefore, to be complete, machinery for the manufacture of smokeless powder should be able to recover, at any rate, the greater part of the solvent. Many machines, especially rolling-machines for the paste, were very wasteful in that respect. Strong efforts should be made to recover the solvent used for the purpose of gelatinization. With regard to the supply of other materials, for most of those required England was dependent on foreign countries. Cotton was obtained from abroad, and also glycerine to a great extent. The nitrate of soda, from which the nitric acid was prepared, was also procured from abroad. In the present state of chemical science he did not think it would be necessary to do as the French had done only 100 years ago, when they had scraped the walls of cellars and swept stables to get the saltpetre required to repel the enemies of the Republic; but England was in rather a precarious state as regards the supply of those raw materials, and therefore should economize them as much as possible. He would make one remark with regard to the accident which had recently occurred in a smokeless-powder works. The matter was still *sub judice*, and he was not quite sure what the cause might have been; but the fact was that the manufacture of smokeless powder, which had been formerly considered to be especially dangerous and was therefore placed under special restrictions, was very safe as compared with the manufacture of the old black powder. Accidents had been extremely rare, and he thought the Author was quite correct in saying that that was the first serious accident which had taken place in the mixing of smokeless powders.

Major, Nathan. Major NATHAN, R.A., observed the Author had mentioned, with regard to the mixing of the acids, that he had found it sufficient to run the sulphuric acid into the nitric acid. His own experience was that that would not produce a satisfactory mixture. Before the present method of mixing by means of air had been adopted, the two acids had been run into the vessel down the same pipe. But it had been found that they did not mix properly, and therefore the mechanical stirrer, which the Author had mentioned, had had to be introduced. Now it had been found that the use of compressed air was a very much better method of mixing the acids than the old mechanical arrangement. Mixed acids could be stored in large vessels without their quality being in any way affected. In fact, it had been found to be a desirable thing to mix the acids, and afterwards to allow time, not only for them to cool, but for the mechanical impurities to settle. The

tanks were so arranged that acids could only be drawn off down Major Nathan. to about 2 inches from the bottom, and there was a baffle-plate which kept back all solid impurities. That had been found, particularly in the manufacture of nitro-glycerine, to be very advantageous; a much clearer acid was obtained thereby, and the nitration was better. The separation of the nitro-glycerine from the acid was much cleaner, and there was not the large amount of what was known as "mud" to be dealt with in the subsequent operations. One or two centrifugals had been referred to. He had not had any experience of what had been called a "nitrating" centrifugal, but in order to produce large quantities of gun-cotton, a large number of such machines would be required. He doubted whether they would be found to be very economical. Any machinery which was subject to the action of acids, and particularly of acid fumes, soon went to pieces; and he could not help thinking that the maintenance of a large number of those centrifugals would be a costly affair. The improvement in the nitration of gun-cotton lay more in the direction of dipping the gun-cotton in an excess of the liquid, and in allowing it to stand in that liquid until nitration was complete. Between $1\frac{1}{2}$ hour and 2 hours would be ample to produce the highest nitrated cellulose required nowadays. As the Author had stated, the present practice was either to use the nitrating centrifugal, or else to dip the cotton waste in tanks and allow it to stand there for a few minutes, then to move the cotton on to a grating, and squeeze out the excess of acid. He thought that would be shortly a thing of the past. He had quite recently made some experiments in the use of aluminium vessels for nitrating gun-cotton, and had found it to be an excellent material for the purpose; it was but very slightly attacked by the acids, was light to handle, and was clean and altogether satisfactory. Using a vessel 13 inches high, 17 inches long, and $13\frac{1}{2}$ inches broad, 4 lbs. of cotton waste could be dipped in 120 lbs. of acid. At the end of $1\frac{1}{2}$ hour the whole contents of the pot were transferred to the centrifugal, the excess of acid was wrung out, and an excellent gun-cotton was obtained. With regard to the arrangement which the Author had described, of the revolving cast-iron table and brickwork, he had found acid fumes, and the weak spilt acid that got about, very quickly went through iron or brickwork, and therefore he thought the arrangement would not be a practical one. He had tried the earthenware exhaust fan described, and had found it to work very well indeed. With regard to beaters, the Author had stated that one of the Hoffsmüller machines

Major Nathan. would produce 5 cwt. of pulp in 5 hours. The ordinary beater of the old-fashioned type with one roll would do that, even if it were not working very well; and if it were working properly, 5 cwt. of pulp could be produced in between 3 hours and 4 hours. He quite agreed with Mr. Reid in reference to the vessel for nitrating glycerine. Any mechanical arrangement in a vessel containing nitro-glycerine was to be deprecated. When making nitro-glycerine, compressed air should be used, that being the best means of keeping up the agitation in those vessels. The rest of the plant described in the Paper really dealt with the manufacture of powder about which he was sorry to say he knew nothing. In Figs. 18, 19 and 20 there was shown a German press for squirting an explosive in a cord form; he could not help thinking that it was unnecessarily complicated. The hydraulic press generally used in this country for making cordite was a far simpler arrangement, and gave excellent results. It was a press with an 8-inch cylinder about 18 inches high fixed on an ordinary hydraulic ram which lifted against a fixed plunger, and the cord issued from the nozzle at the bottom. That machine, working with two men and some boys to handle the cordite as it came out, would turn out between 25,000 lbs. and 30,000 lbs. of cordite in a week. It was simplicity itself; it never got out of order, and never gave any trouble. He did not like the idea of filling one mould while pressing another; the risks were thereby doubled, and if anything went wrong in the filling cylinder there might be disastrous results, as had been demonstrated under somewhat similar circumstances at Messrs. Kynoch's works very recently. The cylinder during filling had caught fire, and the men had not had the presence of mind to throw a pail of water over it and put it out, but had left the building as quickly as they could. The consequence had been that the building had caught fire and the place had become so hot that a filled cylinder in the press itself eventually exploded with great violence. The vacuum drying-arrangement seemed very complicated, and it had one serious objection, as had been proved abroad a short time previously, namely, that the explosive could come in contact with heated surfaces, the temperature of which was indeterminate. One of those machines had exploded with considerable violence. He thought the conclusion had now been come to that only hot water, or water well below boiling-point, should be used in order to heat those drying-chambers. The question of the recovery of the acetone or other solvent used, which had been raised by Mr. Reid, was certainly one of great importance. He

did not know of any economical system of doing it in use in Major Nathan. England, but it was a matter which should not be lost sight of. He hoped that before very long Mr. Reid or someone else would explain how to do it. He could not agree with Mr. Reid as to the granular explosives being the explosives of the future. He was rather inclined to think that, except perhaps for sporting and saluting purposes, they were explosives of the past.

Mr. MELVILLE SMITH wished to make a few remarks from the Mr. Smith. machinist's point of view. The Paper implied that the machinery for the manufacture of smokeless powder should be greatly improved by English firms. Probably the Author did not realise what that entailed. It was rather interesting to see what a variety of machines were used in a factory for the manufacture of granular or flake powders. If lignite were the "base" of the powder, the first machine to be used was a bone-disintegrator; if cotton were the "base," a "teasing" machine, which was a speciality of textile manufacture. Nitrating was more or less a hand operation; "extracting" and washing by heat were the operations of steam laundry machinery. The next machines were those for pulping, and "poaching" machines used in paper-making. The machine for aspirating the pulp was a sort of sewage-extractor. In some powders of granular form, edge-rollers with rounded edges were used, something like chocolate rolls. Then in pugging, the baker's dough-kneading machine was used. Afterwards, if it were a flake powder, it was rolled by a paint-mill, it was cut into grains in a tobacco machine, or was granulated and sifted in a corn-miller's machine sieve. Then it was blended, hardened and glazed, not in the machine which Mr. Reid had mentioned—he had never seen that—but in an ordinary machine used for moulding sugar-almonds. Eventually the expert of Turkish-bath plant was brought in to dry it. The machinery used was drawn from so many trades that it was a little difficult to know how the engineer could improve it. He thought improvements must come from the explosives manufacturers themselves. There was a cherished superstition in the explosives trade that no powder was any good unless made by a process which was secret. If some of those present would, like the Author, adopt a more altruistic doctrine, and would state something of what they knew, it would benefit the community. The Author had indicated the direction in which improvement might be looked for, namely, in the way of making larger quantities at a time. In that course, manufacturers were brought face to face with that ancient relic known as the Explosives

Mr. Smith. Act of 1875, which, besides including blasting-powder, detonators, fog-signals and fireworks, dealt almost entirely with black powder. The manufacture of black powder was a dying industry; from an engineer's point of view it was a dead one. The Act needed to be re-cast and brought up to date, in order to give any advantage to the practice of making larger quantities at a time. He did not wish to imply that the Act was badly administered. He considered the officers at the Home Office who administered the Act did so in the most liberal and intelligent way possible, and thanks were due to them for not interpreting the Act in the narrow spirit in which it had originally been framed. Possible danger from lightning had also to be considered in relation to the question of manipulating larger quantities at a time. Four explosions had been caused by lightning in the past year, whereas in the preceding twenty-five years there had been only one. Perhaps the Author might help to throw some light on that matter, as to continental experience with conductors.

Mr. André. Mr. G. G. ANDRÉ wished to remove a wrong impression which had been created with respect to the accident which occurred at the factory of the Clyde Mills Company. The Author had spoken of the accident as having started in a mixing-machine. There was no evidence to support that view. On the contrary, it had been clearly proved that the mixer had not started when the explosion occurred. There might have been a charge in the mixer, but the explosion was not started by any motion of the blades of the mixer. No doubt it had occurred somewhere outside, but as that was a matter under consideration at present by the Government Inspector, he could not say any more about it. The recovery of solvents from the ordinary kind of sporting powder had been referred to, and it had been implied that this was never done. The Clyde Mills Company had always done so in the manufacture of amberite, recovering between two-thirds and four-fifths of the solvent. The arrangement which he had designed for the purpose was very simple. Immediately after the application of the solvent the wetted grain was put into a hopper, and was then run into a long cylinder about 16 feet in length and 6 inches in diameter. Through that tube it was pushed by an Archimedean screw, the tube itself being heated by a steam coil. The vapour from the solvent was taken through a condenser, and in that way a large portion of the solvent was recovered. It would be difficult to apply anything of that kind to powder of the nature of cordite, or any compound of nitro-glycerine, but it was easily done in powders of the amberite class.

Mr. E. W. ANDERSON remarked that the Author, in describing the pulping-machine for gun-cotton, conveyed the idea that the washing-drum was a new thing. The washing-drum was a very old institution in connection with paper-making, and had been used, he believed, at Waltham Abbey, when the beaters had been first put there. Whether they were used there still he did not know. Referring to squirting multiple cords, up to seventy, the Author's words were: "care being taken that the speed of the cords is the same." He thought it would be a good thing if the Author would give details of the method of securing a uniform speed of the cords, because that had been the difficulty which had originally condemned the practice; at the present time, however, it was coming more into favour. There was also a difficulty in the blending; perhaps the Author would explain how he blended a large number of cords squirted at once. The Author mentioned a pressure of 2,500 lbs. per square inch of nozzle-surface as being, generally speaking, sufficient; he thought it ought to be emphasised that there was another element which entered into the matter, namely, the speed of squirting. The Author had, at the beginning of the paragraph, referred to the rate of squirting, but to make the information more complete he should give some idea of what that rate of squirting was. In a Paper¹ on the subject, which he had had the honour to read three years ago, he had given a Table, derived from actual practice, of various calculated pressures in the pressing cylinders, and the speeds of squirting. The pressures varied between 840 lbs. and 3,200 lbs. per square inch, and the speed varied between 32·5 feet per minute and 603 feet per minute. It was therefore evident that the speed must be taken into account; the statement of the pressure as 2,500 lbs. per square inch being of little use unless the speed were also given. He thought that pressure would give something like from 200 feet to 300 feet per minute with such a dough as was used in the making of cordite and a nozzle of the usual proportions. Thus if a cylinder with one nozzle in which that pressure prevailed and the cord was squirted at say 300 feet per minute, had a second nozzle of the same size added, and if the plunger speed was the same, the two cords would be squirted at half the speed, or 150 feet per minute, and the pressure would be much reduced, probably approximating to one-half. To preserve uniform pressure, the plunger speed must be doubled in this case, so that each cord would then be squirted at the rate of 300 feet per minute.

¹ Minutes of Proceedings Inst. C.E., vol. cxxxii. p. 69.

Mr. McDonald. Mr. G. W. McDONALD said the question of nitrating in pots *versus* nitrating in centrifugals had been raised. It must certainly be claimed for the method employed at Waltham Abbey—the Abel method as Mr. Reid had called it—that it really gave the best possible results from the nitric acid. At starting there was about 20 per cent. of nitric acid, HNO_3 , in the mixed acids. The cotton was dipped for a few minutes in a pot, was then taken out and squeezed, and contained fourteen times its weight of mixed acid. It was next placed aside to undergo nitration during 24 hours. The result was that the 20 per cent. of nitric acid fell to something like 10 per cent. When, therefore, those pots were emptied into the nitrators, the surplus acid contained only some 10 per cent. of HNO_3 , and the acid retained in the cotton which was lost by being put into the washing-tanks and thence carried away, could only amount to about 10 per cent. of the total quantity used. On the other hand, in dealing with centrifugals, a common practice in continental factories was to allow nitration to go on for only $\frac{1}{2}$ hour, which was quite sufficient to give the maximum nitration in the first instance of 13·2 per cent., and the HNO_3 only sank from 20 per cent. to something like 17 per cent. The result was that about 17 per cent. of HNO_3 was transferred to the washing-tanks, and was carried away in the cotton. It was easily seen that from the point of view of economy—although it might be only slight economy—the Government method of only losing 10 per cent. of acid was to be preferred to the other method of nitrating with centrifugals and losing 17 per cent. The question of the maintenance and the life of nitrators had been raised by Major Nathan. He had had some experience of them, and he had found that at the end of about three years the lids of the nitrators began to fail rather badly. There was a ridge underneath the lid, fitting into a groove to prevent the escape of acid fumes, and that began to be strongly attacked at the end of three years. Even with the exhaust, a large amount of nitric-acid vapour came through into the work-room. He was glad to notice the improvement which Messrs. Selwig and Lange had made, as shown in Fig. 4, by carrying the exhaust-pipe out almost parallel to the top of the nitrator into the earthenware exhaust-pipes. His experience had been that the old form of nitrator had often led to what was known as the “firing” of the centrifugals. Unless those pipes were kept perfectly clean, there was a strong tendency in moist weather for the nitric-acid vapours to condense and to drip back into the nitrators, and that was often the cause of the firing of the gun-cotton. The question of

nitration larger quantities at a time had also been raised. Con- Mr. McDonald.
sidering the somewhat violent and unpleasant effect of the firing of a centrifugal containing 30 lbs. of gun-cotton, which, though it did not do any permanent injury, left the room full of fumes, dealing with much larger quantities would certainly be inadvisable. He thought the Nobel Company had taken out a patent for nitrating about 100 lbs. at a time, but if that charge were to fire, the results would be somewhat serious. Very often the nitrators fumed off quietly, but for the first time in his experience, a few days previously, there had been a rather loud report, which was certainly an unusual thing.

Mr. B. BLOUNT said there were one or two chemical points which Mr. Blount.
had interested him very much, and he would ask the Author to enlighten him upon them. It must be remembered, in looking at the industry, which had now assumed very large proportions, that it was practically a series of laboratory operations which had had to be translated into engineering practice, and that translation had been difficult. The very term "smokeless powder" showed the ancient origin of the industry. Cordite was not a powder; but there was no generic word to denote that and similar high explosives, except the word "powder." This little piece of history was only useful in showing how that particular industry had struggled up; and he believed it was still struggling. Looking at the manufacture broadly, it appeared singular that the nitration of cellulose should still be effected in a slow and discontinuous manner in small units. He did not suppose that anyone with the smallest chemical knowledge would fail to see the many difficulties which would be encountered in attempting to alter that; but he would put it to the chemists who concerned themselves particularly with explosives whether some continuous and systematic nitration was not feasible. Was it possible to conceive of cellulose being conveyed by some form of feeder against a stream of acid flowing in the opposite direction, the most highly nitrated cotton always coming in contact with the strongest acid, and the spent acid with the cotton about to be nitrated—thus avoiding the difficulty which had been alluded to of turning out in the finished nitrated material a vast amount of acid which had to be washed away and lost, or to be utilized in an imperfect manner to make nitrates? The reference to aluminium as a material for handling these very corrosive acids had interested him greatly. It was a nice material in many respects, and he was glad to hear that it had been used with success, or with qualified success. Although aluminium had proved chemi-

Mr. Blount. cally successful but mechanically weak, it was possible that aluminium alloys of the light class—of the class which consisted of aluminium hardened with a little copper, nickel or silver—would stand equally well chemically, and have more mechanical resistance. The trouble had been the drawing of the rivets, and those who were acquainted with the mechanical qualities of aluminium would not be surprised to hear that that trouble had arisen, but it was a question whether it would occur with a somewhat harder alloy. There was a process devised by Messrs. Lundholm and Sayers which consisted of mixing the nitro-cellulose and nitro-glycerine by agitating both of them with hot water. This had been mentioned as a possible process and one which had been tried, but no definite opinion had been pronounced as to whether it presented such substantial advantages as to warrant its general adoption. The Author might perhaps enlarge upon that point. The recovery of the solvent led to a wider question. If the solvent was alcohol or ether derived from duty-paid spirit, the high cost of these substances evidently made recovery necessary. What the situation was in Government factories he did not know. Perhaps they were exempt from paying excise duty. If so, they were in a very favourable situation compared with private manufacturers who were not so exempt, and who, if they had to use such substances as alcohol or ether, and wished them pure, had to start with duty-paid spirit. That was a manufacturing hardship. He thought there was reasonable ground for a little feeling of soreness when the British manufacturer was found to be competing with his foreign rival who was using much cheaper raw materials. He believed that was one of the reasons which had led Mr. Reid to think that all the materials ought to be produced in England and not have to be imported; though he did not see how such material as cotton could be produced in England.

Mr. Bache. Mr. A. BACHE asked if the Author would explain what constituted the essential characteristic of smokeless powders—whether smokelessness meant perfect combustion at the very instant of explosion, as contrasted with the imperfect combustion of powders emitting smoke; also whether smokelessness implied that the products of combustion were tasteless and odourless as well as invisible. He asked this question because of the calamity which, as would be remembered, had happened on the 25th September 1886, in the Craræ granite quarry at Loch Fyne, where, after the blasting of a huge mass of material, visitors had unfortunately strayed into the bottom of the quarry. There had been nothing to indicate danger,

but it had practically amounted to walking into the bottom of a Mr. Bache. brewer's vat; and several persons had lost their lives thereby, among them the would-be rescuers of those who had been first seen to fall. In that instance 7 tons of gunpowder had been exploded, and the fatal effects had been attributed to the bottom of the quarry having become imperceptibly filled with the invisible carbonic oxide or carbonic acid or both, which resulted from the explosion.¹ He asked further what was the meaning of the designation of "E.C." powder, mentioned on page 162.

Turning to one or two mechanical points, in Fig. 2 the centrifugal drier was seen to be hung on the bottom of rather a long vertical spindle, which was said to be mounted on the top of the casing; in order to prevent it, he presumed, from wobbling, the spindle was made hollow through the top half of its length, with a stationary spindle suspended from the overhead bracket, and extending about half-way down inside the hollow spindle. It was impossible to see what the arrangement was on the diagram, or to understand it from the minute representation in the engraving accompanying the Paper. He would be glad if the Author would explain how the steadying was effected, so as to prevent the throw or wobbling of the centrifugal drier at any speed whatever. In the inverted arrangement in Fig. 3, the centrifugal drier was carried on the top of the vertical spindle, above the top bearing, and a contrivance of three loose rings inside a casing was mentioned as a provision against oscillation. He would like to understand why it was that in the plan the three rings were shown to be thrown out at equal angles of 120° to one another. Were they so guided radially? and if so, how could they affect the balancing? If not so guided, would not all three fly outwards together towards the same heavier side, one above another, and thereby aggravate the oscillation, instead of mitigating it? Perhaps the Author would also state whether he had himself had any experience of the working of these particular arrangements, shown in Figs. 2 and 3, in comparison with the well-steadied spindle in Fig. 1. There the spindle had a good footstep and an amply long bearing at the top, and was thereby supported from any possible wobbling throughout the whole of its length. In contrast however with the long bearing at the top, immediately above it the centrifugal drier itself was stuck on the top of the spindle by a disproportionately short boss, the length of which was scarcely more than the diameter of the hole. The

¹ "The Mining Journal," 1886, pages 1175 and 1489.

Mr. Bache. same point must have occurred to others, because in Fig. 4, where there was a similar centrifugal drier hung by a boss at the top, the boss was fully twice as long as the diameter of the hole, and must therefore make a much steadier attachment.

Dr. Lewkowitsch. Dr. LEWKOWITSCH could not claim, like most of the previous speakers, to have any intimate knowledge of explosives factories, having only visited them because he had something to do with the manufacture of glycerine for them. In that connection he might allay the fear which Mr. Reid had expressed. He thought that as much glycerine was now being produced in England as would suffice for all present uses, and in fact large quantities were exported. Although exported as crude glycerine, still the facilities were such that all distilled glycerine required for explosives could be supplied. With regard to history, the date of the introduction of smokeless powder was a matter of general interest, and in that respect he might say that the practical use of smokeless powder had been only proved during the Chilian War. He thought the arrangement for vacuum drying shown in Figs. 23 and 24 was a very clumsy one indeed. It was really nothing but the translation of an awkward laboratory apparatus into practice. He wished to ask the Author whether the nature of the explosives required the material to be spread out on shelves. It seemed somewhat cruel to see, as he had seen, that done in work on a large scale, workmen smearing a doughy mass over in small quantities. That the stuff dried rapidly was not the merit or fault of the machine, it was the merit of the vacuum. As to the construction, the form did not appear to him to be a proper one. In the square bottom condensed water would accumulate and a lower efficiency would be obtained than by removing the condensate quickly, as had been done already in the circular vacuum vessel. It appeared to him that for large quantities it would seem to be almost hopeless to try to work with a drying machine of that kind; and perhaps even such explosions as Major Nathan had mentioned would be prevented by causing the stuff to be dried, whilst moving it along by a conveyor screw. He himself had designed something of that nature not very long ago; and he was aware that the patentee of the machine described had himself patented some years ago a similar drying machine to that which he had suggested, and he would like to know why it had been given up.

Mr. Robertson. Mr. L. S. ROBERTSON wished to add one machine to the list of those which had been mentioned. In the Denaby Powder Works, in Yorkshire, there was a machine which was neither a bakers' machine nor yet a laundry-machine, but was, as far as he

knew, a tea or coffee machine. It was used in the factory for weighing out the powder into the cartridges, and it had come from Germany. It had been found difficult to secure uniformity in the weight of the cartridges, and he would be extremely obliged to anyone who could bring to his notice a machine which would accomplish this in an accurate satisfactory manner. Mr. Robertson,

The AUTHOR, in reply, said he would answer very briefly the various questions of importance which had been put. A machine of the kind asked for by Mr. Robertson was made by the Pulverfabrik Troisdorf, the design of which had been described in an English patent and elsewhere.¹ The machine was most ingenious, and he had seen about forty of them working in one small room. It was driven by a pulley. The powder ran into a glass tube and into a funnel, and that funnel acted on a little balance, the knife-edges of which were double and placed in such a manner that if the load was too great by the fraction of a gram, the knife-edge was thrust on one side and the funnel let the powder drop. If it was too small the same thing happened on the other side. If it was correct the powder fell into the cartridge and this revolved on a table to be bulleted and necked, and instruments were provided to make sure that the bullet and the powder were really in their places. If not, there was again a claw which would cause the cartridge to drop down. The machine worked automatically in a glass case; no one could touch it, and it gave the greatest satisfaction. He had not cared to touch upon those matters in the Paper because they were outside the manufacture of smokeless powder. A great debt of gratitude was due to Mr. Reid, who had been the first man to make a practical smokeless powder; but in the Paper he had purposely not described at any length the machines for smokeless powder of the kind Mr. Reid had referred to, because the machinery was so extremely simple. There was really nothing to be gained from the study of those machines from an engineering point of view. The revolving drum was about the crudest possible instrument for making granular powder. Some of the difficulties had been overcome by lining the drum with linoleum, which fact he had not felt justified in stating in the Paper without Mr. Reid's consent. He had not said much about the machines used on the Continent, because to experts the mere mention of an oscillating table or tray with a sieve was quite sufficient to indicate how the powder was made. Objection had been taken to his statement that the mere running of the sulphuric acid into The Author.

¹ "Arms and Explosives," 1895, p. 89.

The Author. the nitric acid produced a perfect mixture. Those who were acquainted with mixing on a very large scale, as in a large powder-factory, would know that it did not mean merely having a vessel and running the sulphuric acid into the nitric acid; but that it meant also running it out again, pumping it up some distance, and bringing it to nitrating vessels. In fact, it simply came to the principle of the funnel, in which by running two liquids together a very fair mixture could be obtained. Acids made in that way had been tested for a number of years by two chemists under his instructions, and it had been shown that whether the acid was tested fresh or after standing 24 hours the difference did not amount to 0.05 per cent. Therefore he considered that was a very good way of doing it. However, if compressed air was available, and condensing plant was also at hand to condense the nitric acid vapours necessarily evolved in the blowing process, that well-known method of mixing might certainly be adopted. But everyone had not the privilege of a Government factory in not being subject to the Alkali Act, which required the condensation of every particle of acid that went into the air. He had seen that often enough in various other factories, where that method of mixing was adopted. It had also been mentioned that the centrifugal charges ought to be lifted out and drowned in water bodily. That was done. A German firm made a nitrating centrifugal with an earthenware basket, instead of an iron one, the arrangement being such that the whole thing was lifted out and dipped into water. That seemed very nice, but he did not think it was practicable. If it were considered that the diameter of such a drum was about 3 feet 3 inches, and that it was tightly packed with gun-cotton in a very sensitive state, it would be seen that the water would not penetrate the cotton in a moment, dangerous heating would occur, and the chance of firing that charge would be very much greater. Opinions might be divided as to whether it was necessary or not, but he personally had no special liking for it. In speaking of the material for nitrating and wringing-apparatus, Mr. Reid had remarked that he had found aluminium to be much more corroded by mixed acids than by nitric acid alone. This had been contradicted by Major Nathan's statement, that he had found it an excellent material for the purpose. He could claim the merit that, after seeing a nitrating-apparatus made from aluminium at Mr. Hermann Güttler's works at Reichenstein, he had advocated its use with such success that not only explosives factories, but also chemical works were now very largely using this material. It had certainly been Sir

Frederick Abel's merit to have insisted upon thorough purification, together with compression, in order to make gun-cotton serviceable, but the process of pulping for such purification had been patented by John Tonkin as early as 1862. With regard to knotters, it had been found that a good deal of time in pulping could be saved by them, and at the same time more thorough solution could be effected, which had its influence upon the uniformity of the powder. The use of mechanical agitators in nitro-glycerine apparatus was certainly not altogether desirable. However, continental factories that used them stated in their favour that the compressed air threw the acids upwards only, and that therefore the addition of the screw, which moved downwards, effected a better mixture, whilst they also affirmed that they never had an accident with them. It had been very interesting to hear from Mr. Reid how the "E.C." powder was made; one or two little details that had not been known previously would interest powder-manufacturers very much. With regard to the dependence of England upon the Continent for the raw materials, he thought that Mr. Reid with a grain of truth had exaggerated very much. The fact was that England produced far more cotton used for the manufacture of gun-cotton than any other country. For a long time continental factories had obtained it from Manchester. There were some factories in Germany which made it, because the German government required home-made cotton. With regard to acetone, the price was not almost double what it had been before the war. It had risen recently about 20 per cent., but England need not depend entirely on the Continent for it. The acetone factories in England which had given most satisfaction had—he spoke in all modesty—been built by himself; amongst them was one for the Government, which produced a very large quantity, and the moment the price became a little higher other factories would find it profitable to make it. As to glycerine, Dr. Lewkowitsch had stated that England was now perhaps one of the largest glycerine-producing countries. Major Nathan had mentioned that in future improvement would lie in dipping the cotton for two hours in a larger quantity of acid, and that that practice was about to be adopted. It had been advocated on the Continent at least 15 years ago, and it had been adopted on a very large scale in a factory which he had built 14 years ago. In fact, the gun-cotton produced there had never been surpassed. He welcomed the step referred to because it was the proper one and the only way in which an absolutely uniform nitrocellulose could be produced which was so essential for a good powder. He agreed with

The Author,

The Author. Major Nathan in his preference for the plain hydraulic press as against the press illustrated in Figs. 18 and 19. In fact, the latest design he had received showed the cutting and filling to be done in another room. The press shown in Fig. 20 looked perhaps more complicated than it really was, but even that was too much. He concurred that it would require a great amount of ingenuity and talent on the part of one engineering firm to make all the machinery for smokeless powders, touching many branches of industry, as Mr. Melville Smith had so humorously explained. The firm of Krupp had, however, shown that it was not impossible, and they had fitted a large number of factories—tenders for which had been invited from England also, but could not be given. The question of protection against lightning could not be dealt with in a short reply, but he thought that a building made entirely of concrete, composed of cement, fine river gravel, sand, and some finely-ground iron ore, well connected to earth, would be lightning-proof. At the same time it would be cheap, allow shafting to be fixed, and, according to experiments made by the German military authorities, concrete made with fine gravel fell practically to dust in case of an explosion, and was not thrown to a greater distance than 50 yards on the explosion of large quantities. It had been stated by Mr. Anderson, doubtless on good authority, that washing-drums had been used at Waltham Abbey from the beginning, but it was certain that they had not been known there for the last 20 years at any rate. With regard to the squirting of the powder, it might be ascertained at Waltham Abbey how the problem of a practically uniform speed for 70 cords was successfully solved, but he did not feel at liberty to say more about it. The blending also presented no difficulty, considering that the 70 cords came from one mould. With regard to the pressure, the statement in the Paper was quite correct and clear, if not looked at merely from the standpoint of the former cordite presses, which squirted a maximum of six cords from one mould. Of course, presses like those for rifle cordite, where the cord was reeled mechanically and allowed a much greater speed, could not be compared with presses for larger sizes. Any presses in which the cutting was done by hand, and where the cut strands had to be taken away by manual labour, had a maximum practicable speed which ought not to exceed 60 feet per minute. Having this obvious limitation in mind, it was necessary to determine the number of nozzles of a given size that could be placed in a mould, consistent with uniformity of speed, and then the total pressure to be used was

proportional to the total nozzle-surface. Of course the plasticity The Author. of the dough and the diameter of the nozzles would have to be considered, so that if 2,500 lbs. per square inch of nozzle-surface (not to be confounded with the area of the mould) were sufficient for cords of say 0·5 inch diameter, with a given dough, that pressure would have to be much increased for cords of say 0·05 inch diameter on account of the friction, in order to maintain the same speed. The amount of increase would have to be determined by practical experiments for each kind of powder-mixture. There must have been a mistake somewhere in Mr. Anderson's calculation that a pressure of 2,500 lbs. per square inch of nozzle-surface could give anything like a speed of 300 feet per minute. He considered Mr. McDonald was mistaken in his comparison of the merits of the "potting-out" system and the continental one. In order to get the same degree of nitration of the cotton the same quantity of nitric acid was required in both cases, and after wringing the gun-cotton the same amount of acid remained in it and was washed out. The advantage was rather on the side of the continental system, because in "potting-out" the cotton kept about eleven times its weight of acids absorbed, which after treatment with the centrifugal were not used again for nitration, whilst with the continental system, the whole of the acid was extracted and brought up to standard strength again. Quite recently a nitrating-apparatus following the lines indicated by Mr. Blount, at least in part, had been patented, but it was very doubtful whether any such apparatus could be successful. It would necessarily have to handle large quantities of acids, and the escape of fumes could not be avoided, whilst uniformity of the gun-cotton would be almost precluded. The Lundholm-Sayers method was not a mere proposition, but was a very successful process used in all ballistite factories. No doubt the rare use of ether-alcohol as a solvent in this country was due to excise duties and regulations. Some useful remarks had been made about the vacuum drying-apparatus. He had only described impartially machinery in existence; and many factories both for explosives and for aniline dyes, used the Passburg apparatus and seemed to be satisfied with it. With regard to the smokelessness of powder, he thought Mr. Bache would find his question fully answered in any good book on explosives. Briefly speaking, the combustion was perfect, and therefore there was no smoke. As far as smell was concerned, unfortunately in battle there were many things which could not be helped, and some smell would probably remain whether black powder or smokeless powder was used. Mr. Bache had evidently

The Author. mistaken the object of the suspension of centrifugal machines. They should not be kept perfectly rigid, but on the contrary the basket should be free to oscillate until it had found its equilibrium. The name "E.C. powder" denoted "Explosives Company's powder."

The President. The PRESIDENT congratulated the Author on the Paper, which had evoked such a hearty discussion.

Correspondence.

Messrs. Selwig
and Lange.

MESSRS. SELWIG AND LANGE, of Brunswick, remarked that in no German government factory was the Waltham Abbey process still employed, and the process which was in use was about to be replaced by another. In future only the centrifugals designed by them would be used for the nitrating apparatus in the three government factories at Spandau, Hanau, and Ingolstadt, and leading private factories, *e.g.*, Rottweil and Troisdorf, had also adopted these machines. In most factories using nitrating-centrifugals the time occupied by the nitrating operation was only half an hour; in a few factories it was three-quarters of an hour, and in one factory only it was between 1 hour and 1½ hour. One government factory outside Germany was said to produce gun-cotton, containing between 13 and 13·2 per cent. of nitrogen, by nitrating for half an hour. They had used earthenware fans for the past 4 years for exhausting the acid fumes from nitrating-apparatus. The drowning-apparatus illustrated in Fig. 6, was used only where it was necessary to limit the height. In all other cases the proper outlet-channel for the wash-water, which could be made of any desired length and had a fall of about 1 in 67, was connected by an elbow pipe 10 inches in diameter, to the conical chamber into which the stream of water entered. The quantity of water used was between 100 gallons and 120 gallons per minute. The final slightly acid wash-water could be used for drowning.

Mr. Swin-
burne.

MR. JAMES SWINBURNE remarked that perhaps the most dangerous part of the manufacture of nitro-glycerine explosives was the nitration of the glycerine. It was strange that automatic means of drowning the charge in case of heating were not adopted. The simplest and most perfectly automatic might be controlled by a thermometer, but that involved complicating the working-apparatus. A better plan might be to arrange a platform or floor so that if the operator's weight was removed without a