of the industry in its present state, and not indulge in vaticination. Had Mr. Plaister had access to the sources of information open to themselves he would have been less surprised at the statement of costs which had been given. The Authors concurred with Mr. Leedham White's view that manufacturers of cement had of late years shown themselves eager to improve their methods both in point of economy and in quality of product. The present enterprise of the Associated Portland Cement Manufacturers in adopting rotatory kilns was certainly commendable, and they hoped that, before long, many of the other works under the control of that body would be provided with modern plant. Mr. Blount.

Correspondence.

Mr. E. Candlot, of Paris, remarked that there was no doubt the rotatory process of burning marked a considerable advance in the manufacture of Portland cement; but the resulting economy should not be exaggerated. The figures given by the Authors for the quantity of fuel required by the older process for power and for burning, viz., 17½ per cent. and 43 per cent. respectively, might be correct for English manufactories, but they were certainly not so for French, German, or Belgian works. The maximum consumption of fuel by a well-equipped Continental manufactory, using wet materials containing 45 per cent. of water, was 10 per cent. to 12 per cent. for power and 28 per cent. to 30 per cent. for burning. In works using dry materials it was 15 per cent. for power and 18 per cent. to 20 per cent. for burning (with Schneider or Timm kilns using bricks direct from the presses and containing 9 per cent. of water). This would considerably affect the calculations of the advantages of the rotatory process. He believed also that the figure given in the Paper for the amount of fuel required for burning by that process (30 per cent.) was too low. In all American works which he had visited the amount had been greater, and had sometimes reached 60 per cent. This of course referred to kilns 60 feet in length; an important economy of fuel was obtainable with longer furnaces; but he did not think that the consumption could be reduced below 35 per cent. The fuel required for power purposes appeared to him to have been under-estimated, as rotatory furnaces required a considerable amount of motive power, not only for rotating the Mr. Candlot.

Mr. Candlot. cylinder but also for crushing coal, drying, transporters, fans, etc. Further, it must be taken into consideration that only a special kind of coal, containing a certain quantity of volatile matter and yielding very little ash, could be employed in the rotatory process; and in some countries such coal was costly. On the other hand, with the ordinary furnaces, coke or anthracite could be employed, and sometimes fuel containing as much as 25 per cent. of ash was utilized. In his opinion the maximum saving realised with the rotatory kiln was between 1*s.* 7*d.* and 2*s.* 5*d.* per ton under the most favourable conditions, that was to say, coal being cheap and labour dear. With reference to the Authors' statement as to the output of the Schneider kiln, he pointed out that kilns provided with forced draught on the Hauenschild system easily turned out 120 tons per week; the Timm kiln, which belonged to the same class, produced as much as 150 tons per week; and the Hoffmann kiln had an output of 70 tons per day—a kiln with twenty chambers producing 450 tons to 500 tons per week.

Mr. Carey. Mr. A. E. Carey remarked that, although the Paper was of great interest and value, the results therein stated were hardly comparable with the present practice on the Thames and Medway, as the Authors, in so far as they referred to the Hurry-Seaman system, apparently dealt exclusively with the dry process of manufacture. Their remarks on the Bronson Portland Cement Company's Works did not imply that the Hurry-Seaman process was there adopted, nor did they give the comparative cost of production. Inasmuch as at these works the fuel used was petroleum, the Authors' notes on the production of cement under the wet process hardly gave the means of comparison with practice in the London district, where the wet system was exclusively in vogue. The figures given in the Paper, therefore, did not conclusively bear out the Authors' contention, in so far as the question of cost of manufacture on the Thames and Medway was concerned. When the Ransome process had been under trial he had had occasion to take particular note of the results attained, and some of the cement made in the Ransome cylinder, tested by him, had given extraordinarily high results for tensile stress. It had been perfectly obvious, however, that with the short cylinder then adopted there could be no effective control of the heat, and the system generally had clearly been of a highly experimental character and very erratic in results. With regard to the Hoffmann and Dietsch kilns the Authors had stated that the amount of fuel necessary for drying was somewhat greater

Mr. Carey.

than that needed for burning, and they proceeded to give the total amount of fuel required (*i.e.*, for drying and burning) as between 35 per cent. and 40 per cent. on the clinker. It was easy to obtain a guarantee that the amount of fuel required with artificial drying should not exceed 10 per cent. on the clinker, and in actual practice it was considerably less. Turning to the broad question of the rotatory system as compared with the use of fixed kilns, either of the chamber-kiln type or of the shaft-kiln type, in this country there were at the present time no installations where the rotatory system had been in steady operation, and from the working of which accurate data were forthcoming. The use of the rotatory system in Germany was firmly established and was rapidly increasing. The Authors had merely made a passing reference to that system as now carried on at Hemmoor, and their views in greater detail would be of interest to English manufacturers. It was there in regular use under the wet system of manufacture, the kilns being 98 feet in length. In the United States the rotatory system had been in steady operation for a considerable period, and probably the major portion of the output of that country was now produced by such kilns. In recent extensions of Belgian and French factories shaft-kilns had been the most favoured plant, but in England chamber-kilns were in overwhelming predominance. It was very doubtful whether the so-called patent rights in rotatory kilns could be maintained if disputed, and the Authors did not describe any features which could be called unquestionably novel and patentable. The covering of the lining of fixed kilns with salt and the use of an adherent coating of clinker as a protection to the lining were extremely old expedients; in fact, the rendering of the inside of cement kilns with slurry (which on burning of course became clinker) was probably coeval with the manufacture, and the only suggestion of novelty made by the Authors was the beating of the clinker in a hot state on to the lining of the rotatory kilns. In Germany, however, the difficulty of getting the kiln-lining to stand appeared to have been overcome without resorting to this practice. The moistening of the clinker as it came away from the kilns was also quite an old expedient. Setting aside as indisputable the fact that by the rotatory process cement of the highest quality could be made, although an excessive amount of power was required for grinding under that process, the whole matter resolved itself into one of cost of production; and the Authors did not anywhere state the capital outlay necessary for the installation of the Hurry-Seaman system, nor attempt to compare it with the old

Mr. Carey. system of kilns. The figures given referred exclusively to the cost in fuel and labour of manufacture, and it must not be forgotten that the statements contained in the Paper, so far as they related to the rotatory process, were in the nature of estimates or ideal statements. The cost of production of Portland cement by the old process in the Thames and Medway districts was easily ascertained. This the Authors gave as 19*s.* 3*d.* per ton of cement. At a works recently built by Mr. Carey on the Thames, with coke at approximately the price given by the Authors, the actual cost of production, including all the items of their statements, was 17*s.* 4*d.* per ton of cement. The comparative figures given in the Paper were not very convincing, as under the rotatory process the item of labour was given at 2*s.* per ton of cement, whereas under the old process that item was put down at 4*s.* 9*d.* per ton, showing a saving of 2*s.* 9*d.* due solely to economy of labour in burning and subsequent manipulation in grinding. As the ordinary piece-work rate from the wash-mill to the dry grinding-mills was only 1*s.* 9*d.* per ton, and the item of grinding remained fairly constant under both systems, it was a little difficult to reconcile these figures. He presumed that the Authors intended to include in the item "raw materials delivered at mill," the whole of the labour involved in getting the raw materials and their delivery, in the case of the rotatory kiln, to the dry mills, including drying; whereas under the old process the same item included the getting of the raw materials and their delivery to the wet mill. The Authors had taken the cost of coal for burning, under the rotatory process, at 10*s.* per ton, and that of coke for burning, under the old process, at 15*s.* per ton. These figures did not accord with recent prices for either commodity. The prices at a leading factory on the Thames, including labour *ex* barge, for the year 1900, had been, for steam coal 19*s.* 9½*d.* per ton, for coke 20*s.* per ton. At the same works the average prices for the past 9 years had been, for steam coal 14*s.* 2*d.* per ton, for coke 13*s.* 9½*d.* per ton. The assumption of purely arbitrary figures vitiated the inference drawn by the Authors, and, adjusting their statements to the above prices, the costs would be :—

	By rotatory system. Per ton.		By old process. Per ton.	
	s.	*d.*	*s.*	*d.*
Year 1900	17	10	22	2
Average of past 9 years	15	0	18	6

The Authors did not state whether their figures included the cost of the fuel necessary for drying the clay, and also the cost

Mr. Carey.

of grinding the coal used as fuel. Moreover, they gave the amount of ground coal used as fuel for burning, under the rotatory process, as 30 per cent. on the weight of the clinker produced; whereas by some shaft-kilns, notably the Schneider and Steyn kilns, the amount was brought down to 20 per cent. of unground coke, or less. In the item of labour, again, these kilns compared favourably with the figures given by the Authors. So far as he had been able to ascertain, under the German rotatory system an outlay of £5,000 was needed for a production of 200 tons per week, a figure considerably in excess of the normal average capital cost of chamber-kilns to produce the same output. The prospectus of the Associated Portland Cement Manufacturers had stated that a sum of over £120,000 was being expended on new plant in their works for the yearly production of about 160,000 tons of Portland cement on the Hurry-Seaman principle. These figures represented £7,500 for a 200-ton installation, an excess of 50 per cent. over the cost of the German plant. It would be instructive if the Authors would supplement their figures by a comparative statement of the cost of producing cement on the Hurry-Seaman system under the wet process. The changes in methods of manufacture which had been initiated within the last few years were a source of anxious consideration to those who were responsible for advising on the construction of new or extended works. The question of the life of the structure of the rotatory kiln as compared with that of the fixed kiln, and of the amount of depreciation which should be allowed, were points as to which data did not exist at present. There was no doubt that no hard and fast rule could be laid down that any one process of manufacture was of such proved superiority as to be likely to hold the field exclusively; the local conditions of cost and the nature of the raw materials and fuel, as well as the cost of labour, must remain vital factors in deciding the most suitable type of installation for any particular locality.

Mr. Erith.

Mr. Charles Erith remarked that, having been for seven years identified with the introduction of American methods into Europe, he would not be accused of prejudice in saying that he had much doubt if the rotatory system would prove suitable to the English wet-process cement-manufacturers. Even in America he had never heard it claimed that there was any economy of fuel in the rotatory process; in fact, the contrary had been freely admitted. The Paper showed clearly that the amount of fuel required at the Atlas Works was 30 per cent., and it was

Mr. Erith. alleged that the amount required for treating slurry at the Hemmoor Works was also "about 30 per cent."; but this was obviously a mistake, as it had never been claimed that slurry could be burnt at the same cost per ton of cement as dry raw materials. It was not denied that, with the vertical shaft-kilns continuously worked, which were so common on the Continent, and had been lately introduced into this country, dry-process cement could be burnt with a fuel consumption of 15 per cent. The question therefore arose whether the saving of labour and the incidental advantages outweighed the doubling of the cost for fuel. Further, while ordinary coke was used for vertical kilns and the working was simplicity itself, the conditions were quite otherwise with rotatory kilns. The coal must be first dried, then finely powdered, and mechanically injected. All the mechanism must be exactly speeded and not allowed to vary. Coal-dust was too explosive to be stored, and it was therefore injected as fast as it was prepared. Stoppage of any part of the plant stopped the whole system. Of course the remedy for this lay in highly-skilled mechanical management, as usual in America; but anyone acquainted with the typical English works knew that no such technical skill had hitherto been either usual or necessary. Much stress had been laid on the aeration of the clinker; but there was nothing whatever to prevent users of vertical kilns from cooling and aerating their clinker in just the same way. His belief was that a good drying-system for the raw materials, with vertical-shaft continuous kilns, and mechanical methods of handling the materials, would do everything that was claimed for the rotatory process at less cost and with much less complication. It required no revolutionary changes and only moderate expenditure, and involved no risk. He drew attention to the fact that there was no monopoly in the rotatory-kiln process, and that numerous installations on various systems had been described in the technical press.[1] He might quote the following conclusion arrived at in December, 1898, by Mr. F. H. Lewis, the writer of one of these articles:—

"The high temperature of the rotary kiln is peculiarly adapted to the hard raw materials of the Lehigh Valley, which are comparatively free from fluxing salts, and it has worked well with similar raw materials in Ohio and Michigan. Whether it can be as successfully applied to materials containing the high percentages of fluxes which are found in some of the European mixtures is

[1] *E.g.*, various articles in *The Engineering Record*, 1898 and 1899. (Recently published in book form as "The Cement Industry.")

perhaps questionable. It is possible that for such materials shaft kilns are better. With this exception, however, the rotary kiln seems to have advantages for American conditions which cannot be questioned." Mr. Erith.

It seemed to him that nothing had since occurred to modify the foregoing opinion. The results of the experiments about to be made at English works were looked forward to with much interest, and it would be useful to get some accurate information regarding rotatory kilns already started in Europe, about which so far nothing definite was known.

Mr. W. F. GOREHAM remarked that the many rumours which had been current during the past 2 or 3 years had had the effect of making everyone interested in cement manufacture intensely anxious to know what the Hurry-Seaman rotatory burning-plant was like. From these rumours the feeling had been gradually arising that English cement-makers, and those undertaking the design of cement-works, were about to be compelled to acknowledge that they were behind the times, and that they must learn from America how to bring their works up to date. The idea had been that something was to be put before the English cement-maker which was novel, more perfect, and more economical than anything at his command, even with all the different improvements adopted on this side of the Atlantic. However, on considering the Paper carefully it appeared that this fear was not by any means warranted. In the first place the Hurry-Seaman burning-plant appeared to contain only two novel features worthy of notice. The covering with clinker of the brick lining of the burning-cylinder was an old practice. One well-known firm some 15 or 20 years ago appeared to have realised the value of this practice to such an extent that a man had been appointed to a certain number of kilns, to go into each one when drawn, and, while it was hot, to pug up the kiln with slurry, with which, however, a certain amount of loam had been mixed. Other firms were said to have used slurry alone for the same purpose. The novelty in this case, therefore, consisted only in the patting down of the clinker when in a plastic state. He understood that at Hemmoor, however, no such measures were taken to protect the lining. Kilns existed in which there was no lining whatever in the shape of bricks, etc., the walls of the kiln being formed of cast-iron rings which were prevented from reaching a melting heat by having outside gills, such as were used in ventilators, to present a large cooling-surface to the air. Such kilns had been adopted in a large number of the new burning-plants or extensions of existing plants erected in Belgium during Mr. Goreham.

Mr. Goreham. the past year or two, practically the whole of the extensions in that country taking the form of shaft-kilns. This was mentioned because, if the import of cement into this country in the month of January last might be taken as a criterion, Belgium sent some seven-tenths of the total importation, and was therefore the chief Continental competitor in the sale of cement in this country. In this type of shaft-kiln the cement did not stick to the sides of the kiln. In another cast-iron shaft-kiln holes were made through the rings, but as to the success or failure of this type there appeared to be little or no data. The cooling-cylinder was, of course, not new, and, although it was apparently a very good attempt to reduce the loss of heat which appeared to be unavoidable with the rotatory system, it did not altogether prevent that loss, as was proved by the fact that the system consumed 50 per cent. more fuel—this being prepared coal instead of coke—than shaft-kilns. The second apparent novelty consisted in making the crusher part of the kiln and wetting the clinker there. There was nothing new in putting water on the clinker at the crusher, and in his opinion the retention of the crusher at the mill, and the addition of water to the clinker there was preferable; but apparently one of the reasons for doing this at the kiln was to cool the clinker by taking up as much as possible of the heat that was wasted with the rotatory system. This heat was utilized in the shaft-kiln in heating the air on its way to the fire-zone in the kiln, and resulted in the clinker being cold enough to grind when it reached the bottom of the kiln. The gases leaving the kiln also parted with so much of their heat, which was utilized in heating up the slip on its way down to the fire-zone, that the hand could be held in them and, so far as heat was concerned, it was quite possible for a man to stand on the top of the slip in the kiln. His preference for watering the clinker at the crusher when forming part of the mill was based on the result of experiments he had made some years ago, by taking clinker crushed small, soaking it in water for a time, then drying it and grinding it in the ordinary way. This had passed practically the same tests as if it had not been wetted, proving that the water had no effect on the cement until it was ground to the marketable form; and it appeared that there would be far less chance of the water having the desired effect if it were added to the hot clinker at the kiln—and therefore subject to varying delays before reaching the grinding-machines, and to irregular evaporation on the material, even if added in larger quantities—than if

Mr. Goreham.

it were added at the crusher at the mill, and so delivered at once into the hopper for grinding. With regard to the cement clinker being better from the rotatory system, he did not quite agree with the Authors on this point. If clinker was well burnt, it did not matter, in his opinion, by what kiln it was burned, and it was unimportant whether the lumps were large or small, as the crusher would deal equally well with either. With the shaft-kiln, of which he had had experience, the half-burnt stuff averaged only about 5 per cent., consisting, as a rule, of lumps that were easily picked out. This sorting cost probably about $\frac{1}{4}$*d.* per ton, and the clinker, when ground, gave a perfectly good quality of cement. He was not quite clear whether the estimate given in the Paper of the costs of the suggested system, for comparison with the usual type of works, was for the wet or the dry process, and he would like to know, if the dry process was referred to, where the cost of preliminary drying of clay was included, and, if the wet process was meant, whether it was necessary to double-grind the slurry, or whether ordinary slurry would do. In the latter case, where was the cost of drying and grinding coal included? He did not think the prices of coal and coke were usually in the ratio given in the two Tables of costs. In these the coke for burning was put down as costing 5*s.* per ton more, *i.e.*, 50 per cent. more than the coal for burning. He had an impression that until some 2 or 3 years ago, the price of coke for a number of years had been very much lower than 15*s.* per ton, being only about 11*s.* or 12*s.* per ton; and that if this comparison were made for each year at the then current prices of coke and coal, some of them, at any rate, would not show anything like the saving in cost of fuel per ton of cement. In comparing different systems of manufacture, the all-important question—the quality of the cement being equal—was cost, both cost of production and cost of installation of plant. He had been connected with the starting, some time ago, of what he believed to be the latest dry-process cement works erected in the kingdom; for the laying out, building and starting of which he had had the sole responsibility. This works had been laid out for an output of 300 tons per week; and partly because the extensive use of the shaft-kiln on Belgian material could not be taken as absolute proof that it would work as satisfactorily on English material, as well as for the purpose of seeing whether any improvement could not be made in the details before ordering the second kiln, only one of the two kilns necessary for that quantity had been put in, although the other would be erected very shortly. The

Mr. Goreham. output of the works was therefore at present only 150 tons per week. However, he had the best authority for saying that the total cost of the cement, even with this small output, was only 13*s.* 4*d.* per ton. It was estimated that when the works were complete the cost would be only between 12*s.* and 12*s.* 3*d.* per ton. Again, the number of men for an output of 2,800 tons per week, as estimated in the Paper, was 159. When the works referred to were completed, the number of men engaged, exclusive of those digging the raw material, as in the estimate in the Paper, would be eighteen men and four boys, equal to, say, twenty men. If units giving 300 tons per week were multiplied to give 2,800 tons per week, the number of men necessary would be apparently 186; but in putting up one works for 2,800 tons per week with this plant, instead of so many units of 300 tons per week each, the 186 men would be reduced to about 160. From the foregoing it was evident that with shaft-kilns it was not only possible to make cement more cheaply than with the Hurry-Seaman plant as estimated by the Authors, but that it was being done at the present moment in England. It might be admitted, however, that it was difficult, if not almost impossible, to alter an old works to make cement quite as cheaply as with a new works laid out to economize labour in every way possible; and it was also questionable whether the low cost of cement in the Atlas Works was not due more, or as much, to the works being new and well laid out. The cost of installation was not mentioned, although it was undoubtedly of great importance and quite relevant to the subject of the Paper; but the cost of a burning-plant on the Hurry-Seaman system had been published some few months since by, he believed, the owners of the licence, the cost given being £120,000 for an output of 160,000 tons per year. These figures showed that the cost of the Hurry-Seaman plant amounted even in large works to 15*s.* per ton of output per year. The new works mentioned above, when completed for an output of 300 tons per week, or 15,000 tons per year, would have cost less than £15,000, or about 19*s.* 3*d.* per ton of output per year, the kilns, brick-machine and dryer costing £4,500, or 5*s.* 9*d.* per ton of output per year. To simplify a comparison of these figures with the Hurry-Seaman process, 20*s.* and 6*s.* per ton per year might be taken instead of the figures mentioned. On a plant turning out 2,800 tons per week, the shaft-kilns, drying-plant, and brick-machines, even if no allowance were made for the reduction in cost of a large complete plant as compared with a small one would

Mr. Gorcham. only amount to £43,680, while the Hurry-Seaman plant would cost £109,200, or £65,520 more than the shaft-kiln system. The interest on this sum at 5 per cent. would amount to £3,276 per annum, or between 5*d.* and 6*d.* per ton on the output, which, if added to the estimated cost of 13*s.* 11*d.* per ton, would increase the cost of the cement to nearly 14*s.* 4½*d.* per ton, or more than 1*s.* per ton above the actual cost given for the shaft-kiln system. Adopting the Hurry-Seaman process instead of the shaft-kiln system, the other departments of the works being equally well laid out and costing, as they should do, about 14*s.* per ton of output per year, the total cost of the works would be 45 per cent. more than with the shaft-kiln system, and, allowing the fair outside figure of 20*s.* per ton of annual output for the purchase of site, raw material and working-capital in each case, the total capital necessary for the two systems would be £334,880 for the Hurry-Seaman system, while for the shaft-kiln works it would only be £291,200. A profit which would pay a dividend of 10 per cent. with the shaft-kiln system would pay only a little over 8½ per cent. with the rotatory system. The foregoing figures were all based on the assumption that the estimate given in the Paper for the rotatory plant was for a dry-process works. If this were incorrect, and they were intended for a wet-process works, the difference was slightly reduced. The cost of making cement by the wet process would be about 1*s.* 2*d.* per ton more than with the dry, thus bringing the cost of manufacture with the shaft-kiln system nearer to the cost by the Hurry-Seaman process. The cost of installation of a complete wet-process plant, including grinding- and burning-plant of the shaft-kiln type, would be 21*s.* 6*d.*, or say 22*s.* per ton of annual output. This would make the total cost of a cement-works with the shaft-kiln system only £50,690, instead of £65,520, less than that of a cement-works fitted with the Hurry-Seaman plant. The interest on this at 5 per cent. would still, however, amount to over £2,500 per year, thus adding over 4*d.* per ton to the cost of manufacture, and a profit which would give 10 per cent. in the case of a shaft-kiln works would be reduced by nearly 1 per cent. if fitted with the rotatory plant. There did not appear to be, however, sufficient definite information in the Paper to enable a judgment to be formed of its success in working on chalk and clay slurry. The amount of fuel required for the slurry system at the Hemmoor Cement Works was given in the Paper as "about 30 per cent.," but this was not very exact. Nothing was said as to whether the raw material at this works was like the material of the Thames or Medway. The raw material at

Mr. Goreham. the Bronson works was stated to be a marl, and the question arose whether the rotatory kiln would work as satisfactorily with chalk as with this; and whether the variation in the proportion of water would not make it extremely difficult to keep the burning regular. He had had some correspondence on the question of the rotatory system with some Continental makers who had been and were making a study of it, to see whether it was worth adopting, and the general impression appeared to be that the principal difficulty with it was this difficulty of keeping the burning regular, seeing that it depended on several conditions, viz., the control of the heat and the speed at which the material passed through the cylinder, the proportion of water in the slurry being uniform. It appeared that one of these difficulties might have been obviated, or at any rate reduced, in the Hurry-Seaman process by improvement in the method of applying the fuel, but the other two still remained. It should not be difficult, however, to reduce these also.

Mr. Hewitt. Mr. Walter Hewitt thought the thanks of cement manufacturers were due to the Authors for their able Paper which showed what was being done in the cement-making world and the immense amount of time, trouble, patience and expense which had been needed in order to arrive at the present stage. It looked as though something tangible was being done at last to cheapen the cost of production and, if possible, improve the product, and seeing that the process of manufacture fell naturally under only three heads, viz., preparation of the raw material, burning, and grinding, it was surprising how little towards this end had been done for so long a time in this important trade. Twenty-five years to 30 years ago the Goreham washing system had come into operation, and at the same time Messrs. White had dried slurry with the waste heat from kilns, using 40 per cent. to 50 per cent. of fuel for the whole operation. Since then the washing had not been improved upon, and none of the present type of kilns gave much better results. In the grinding it might be said that no real improvement had taken place until the tube-mill had come into existence. Various forms of expensive machinery had been tried with doubtful success, but none of them had had any finality, and, grievous as it seemed to say it, none of the various improvements were of English origin, with the exception of the washing. The rotary kiln, although attempted by Ransome and by Stokes, had failed years ago, and had had to be perfected abroad, and this system, as the records of the Patent Office would show, had been culled from another trade. The ball-mill was of German and the tube-mill of

Danish origin, so that the present English manufacturers could not fairly lay claim to the systems that were now rapidly coming to the front. It was true that plant and methods had been perfected, but no important departures in the manufacture had been made, and manufacturers would like to know more of what was being done abroad in other departments of the industry. He would be glad if the Authors would say what was the cost of the process from the wash-mill on first preparation of the material to the grinding or finishing operation. Mr. Hewitt.

He believed that cement would be eventually burnt by mechanical means with liquid, solid, or gaseous fuel, or a combination of them; but that it would be in the form of a rotatory kiln of the present type was, he thought, somewhat problematical. There was too great a loss of heat by it, and the heat did not impinge directly enough on the material to be calcined to produce regular results, and the hot gases, having to be drawn or forced through the kiln, must necessarily be taken away at a very high temperature, to say nothing of the heat wasted in the clinker just calcined. Whether this loss could be obviated, or the heat utilized after leaving the kiln, remained to be seen. From the figures given by the Authors it appeared that only 20 per cent. of the heat actually contained in coal was used by the rotatory kiln. The main point about the whole system was, in his opinion, the cooling, or more correctly the slaking, of the burnt material as it left the kiln or furnace, and in this lay the secret of the whole matter, not only in this system, but in that adopted by competitors across the water. Slaking was the order of the day, and in slaking lime before using it, it was usual and absolutely necessary to take out all the underburnt, overburnt, and foreign material; but in slaking cement this was not done, the whole of the clinker, good, bad, or indifferent, being slaked either at the kiln with water or at the crusher with water, wet sand, wet ragstone, wet slag, or moisture added in any other way, and so far as present practice went all was apparently put right. He would like, however, to ask the Authors whether, if raw materials were badly prepared, badly washed, or badly burnt, the actual ultimate effect of this slaking on the cement was beneficial or otherwise. In other words, if clinker was badly or irregularly burnt, was it really put right by slaking, and if the clinker was over-limed, did slaking put it right also? If so, it meant that no trouble need be taken with the washing, preparing, or burning, as a badly-made cement could be put right by slaking, and with it the present known tests could be very easily met. That, then, introduced the question whether the present form of

Mr. Hewitt. testing for strength at an early stage was one that would show whether a cement would give stability, because by this plan of slaking, the ultimate strength of a cement in bulk could be obtained quickly. That might be satisfactory for a sample test, but would it be right for using the cement in bulk, and would it be right in the long run? Cements used 30 years or 40 years ago, which had stood the test of time with good results, would now be pronounced useless and not allowed to be used. The question was whether the cement now being made and used, and passed as being of first-class quality after being artificially slaked, compared favourably with those that had stood the test of time. He would also like to have a pronouncement from the Authors as to whether a badly washed sample of cement, that was to say, coarsely ground, when slaked, would not only pass the test, but be a good cement; also whether a badly burnt or over-limed cement, when slaked, would come under the same category. This was a very important point, not only to manufacturers but to users, and there was little doubt that these methods had been used with great advantage by firms having unsuitable materials, to make them pass present-day tests. It might be that slaking during manufacture was a scientific practice, and that the cement was thereby improved in quality; or this practice might be the means of temporarily improving a bad cement in a degree sufficient to pass the present form of testing. At any rate, in his opinion it was so important a point, that it ought to be set at rest with all possible speed. If slaking was absolutely necessary, as it was now said to be, at some stage between the burning and using, either before or after the grinding, it meant that the present system of aeration was wrong, and that turning cement over and allowing air to pass through it and exposing its surface to the atmosphere did not slake it at all, but made the surface air-dried; because if it was necessary that cement should absorb moisture, this could only take place when there was moisture in the air for it to absorb. Therefore to slake cement properly after it was ground, it would be necessary to place it in thin layers on suitable conveyers, and to pass it through a chamber containing moisture. Any industry must be the gainer by the reading and discussion of Papers, and it had always seemed to him that any industry of importance, desiring to keep abreast of the times, should have a research department always watching, and following up what was being done in various parts of the world, and making use of it. In the United States and on the Continent, works were published by authority showing how cement should be used, the best means of using it, and also the various uses to which it might be put, many of them strange to English users. This must be an advantage both to makers and users, and he thought it would be a good thing if these various works were translated into English, with additions. He was aware that there were a number of splendid continental books on the manufacture and use of cement if one could only read them. He wished some British publishers would take the hint and publish them; or the various scientific institutions would be doing an invaluable work for the trade and manufactures of the country if they undertook the matter in respect of technical subjects. Mr. Hewitt.

Mr. WILLIAM F. CARR HILL observed that on page 65 of the Paper it was stated that an engine of 2,500 HP. had been erected in the grinding-mill, and it would be interesting to know why such an excessive power was required. Allowing that the four Gates crushers and revolving dryers mentioned required 100 HP., and assuming 400 HP. to be consumed by the conveying- and elevating-plant, &c., there remained 2,000 HP. provided for forty-three Huntington mills, of which probably never more than forty would be working simultaneously. It would therefore be seen that each mill had 50 HP. provided for it. It was stated that thirty mills were required for grinding clinker, which at, say, 50 HP. each meant that about 1,500 HP. was provided for pulverizing the cement-clinker. In several other grinding-systems of which he had had experience, both in England and on the Continent, provision for a much smaller horse-power sufficed for grinding 2,800 tons of cement-clinker per week (the output of the plant named in the Paper), viz., (1) With ball- and tube-mills the same quantity of finished cement could be ground with an expenditure of about 750 HP. (2) With Griffin pulverizing-mills a still greater saving was shown, as 18 Griffin mills would grind the 2,800 tons of finished cement per week, using only 450 HP. It was assumed in all these cases that the grinding-plant was running continuously. Mr. Hill.

Mr. J. HOLLICK remarked that, reference having been made to the Schneider kilns, he would like to mention that, after seeing these in successful operation in Germany in 1898, he had erected at the works of his late firm, Messrs. Hollick & Co., of Greenwich, one of the first two of such kilns constructed in this country. This kiln had been at work continuously for upwards of 2 years, during which time the output of cement had been about 7,000 tons. The cement was burned with less than 4 cwt. Mr. Hollick.

Mr. Hollick. of coke to a ton of cement, while the quality had proved excellent. He attributed this favourable result to the greater intensity of heat obtainable in this kiln, as compared with others, to the shorter time required for calcining, and to the smaller quantity of ash or refuse from the coke amongst the cement, consequent on the quantity of fuel required for burning being reduced by more than one-half. Much having been said respecting the wear and tear of kiln-linings, he would remark that after the continuous working of the Schneider kiln for the period of 2 years referred to, the lining was certainly not half worn out—a most important consideration when estimating the actual cost of replacements.

Mr. Le Chatelier. Mr. H. LE CHATELIER had had occasion to investigate the subject of magnesia refractory linings. Their use gave rise to two grave difficulties, which did not appear to be always sufficiently understood. The coefficient of dilatation was very high, and the result was that considerable pressure between the lining and the metal cylinder of the furnace occurred during heating, and the contraction during cooling ruptured the refractory lining, and tended to its disintegration. The results of his measurements of the dilatation of magnesia bricks from Eubœa, and of bricks of ferruginous magnesia from the Tyrol, were—

Temperature.	—	200° C.	400° C.	600° C.	800° C.
Dilatation in millimetres of a bar 100 millimetres long.	Eubœa	0·21	0·55	0·85	1·1
	Tyrol	0·25	0·52	0·79	1·02

showing that the dilatation was sensibly the same for the two varieties of magnesia brick, and double that of fireclay bricks. Another important point was that the ferruginous material which agglomerated the Tyrolese bricks melted at a certain temperature and remained indefinitely in the liquid state provided the temperature did not fall. The result was that at high temperatures these bricks had very little durability, and were in fact in a pasty semi-liquid condition. Pure magnesia bricks, however, even if softer under ordinary conditions, retained a much greater degree of solidity when heated. The behaviour of basic bricks was quite different from that of siliceous refractory bricks. The fusible elements contained in the latter dissolved increasing quantities of silica, forming vitreous matter more and more siliceous and less and less fusible. The result was that the materials melted at the first heating solidified progressively by absorbing silica. Basic materials, on the other hand, which did not assume a vitreous condition, did not have the same effect. Mr. Le Chatelier.

Mr. E. Macoir, of Niel-on-Rupell, remarked that, having been acquainted with the rotatory process in use in the United States during the past 15 years, and having seen it at work on the Continent, he had always considered it as destined to replace some day, particularly in the construction of new cement works, the processes hitherto in use for wet as well as dry material. There had remained, however, two important improvements to be made in the plant in order to arrive at this result, viz., the provision of means of controlling the temperature in the kiln, and of obviating the destruction of the lining. Apparently the happy modifications introduced by Messrs. Hurry and Seaman had met these requirements, and had rendered the process more practical and economical. The process of watering the clinker completed the series of entirely mechanical operations of manufacture, and enabled a perfectly sound cement to be produced direct from the works without recourse to the slow, cumbrous and costly process of aeration. The kilns of Messrs. Hurry and Seaman appeared to him to remedy in a favourable manner the inconveniences which had been found to arise in the working of the older forms of rotatory kiln, and to ensure, by regular and practical steps, the advantages of the latter, consisting notably of a considerable economy in fuel and, above all, in labour; and there could be no doubt that these kilns, properly worked, gave excellent results. Mr. Macoir.

Mr. William Matthews, C.M.G., considered that the Institution was much indebted to Messrs. Stanger and Blount for their valuable Paper. Any process which had for its object the improvement of the manufacture of Portland cement, and the cheapening of the cost of its production would be welcomed by engineers, and the more so in view of the continual increase in the use of this material, and the important part it played in many engineering structures. It appeared from the Paper, and there was no doubt much to support the view expressed, that the rotatory process of burning cement would result in the production of a better and more uniformly burnt clinker than was practicable under the existing system of fixed kilns. Although this might generally be the case, in the event of the failure, from any cause, of a due supply of heat even for a comparatively short period, there would be much greater difficulty in picking out the underburnt clinker under the new system than under the old process. In the case of the rotatory cylinders the clinker was comparatively small in size, Mr. Matthews.

Mr. Matthews. say from that of walnuts down to beans, or even smaller; so that great difficulty would arise in abstracting underburnt or unsound clinker, as compared with the old system in which the yellow, or insufficiently burnt portions, were of comparatively large size, and thus easily detected and removed. With reference to the soundness of cement produced under the new process being such as to obviate the necessity for bulking and turning, thus effecting considerable economy in time and money in the use of the material, so much depended on the absolute soundness of the cement, as affecting the quality of the work in which the material was used, that engineers, it was thought, would not be hasty in abandoning the present prudent and safe mode of procedure, until it should have been proved that aeration could be dispensed with in the case of cement produced under the rotatory system without entailing the subsequent blowing or swelling of work in which such cement was employed. In the last-named connection it might be observed that careful observations had shown, on works under the direction of his firm, that the growth in bulk of cement up to six times of turning, due to aeration, was sufficient to pay the cost of the turning operations, so that the actual increase in the cost of the cement used, after aeration, was limited to the expenditure required for storage sheds—an outlay which, at all events under the existing system of manufacture of cement in this country, was amply justified by reason of the increased soundness of the cement which was produced thereby. Contractors for public works bought cement by weight and disposed of it by measure, hence the increase in bulk by aeration, previously referred to, became of importance. Formerly his firm had bulked cement for 2 weeks and turned it twice; experience had shown, however, that further bulking and turning were beneficial, and they now kept cement in sheds on the works, after delivery, for 5 weeks, and turned it five times before use, with great advantage in increasing the soundness of the material.

Dr. Michaelis. Dr. W. Michaelis, of Berlin, recommended the formula

$$\frac{CaO}{SiO_2 + Al_2O_3 + Fe_2O_3} = 2 \cdot 5,$$

instead of the ratio of basic to acid oxides given by the Authors as expressing the approximate composition of a good cement-mixture. However completely the mixing and burning might be effected, the ratio $\frac{CaO}{SiO_2 + Al_2O_3} = 3$ should never be attained, as this always resulted in the production of blowing cement, because

Dr. Michaelis.

Al_2O_3, $3CaO$, even when it was completely fused, could only be hydrated with very considerable increase of volume. The treatment of the clinker with a small quantity of water, about 1 per cent. by weight, had been practised in Germany for the past 25 years, and this plan had been universally adopted there for the past 10 years. In the early eighties he had introduced the method into the works of the Compagnie Nouvelle des Ciments Portland du Boulonnais in France, which he had built; and it had also been used for some years in England on his advice. Basic linings of cement-clinker in the Dietsch kiln had long ago been tried in Germany, but had not come into any considerable use, owing to their slight durability; such a lining was easily disintegrated by cooling of the kiln, and prolonged heating reduced it to powder, especially when it became less basic through taking up ash from the fuel used. The most satisfactory method of making the lining would obviously be to cast or mould bricks from fused Portland cement, since that was much stronger and more durable, or else to use bricks having the composition

$$\frac{MgO}{SiO_2 + R_2O_3} = 2{\cdot}5 \text{ to } 2{\cdot}8.$$

He fully shared the Authors' favourable opinion of the rotatory process, and had expressed his views in similar terms before the Verein Deutscher Portland-Cement-Fabrikanten.[1] It was desirable that the burning should be effected by the use of gas instead of coal-dust. In this way the quality of the product could be considerably improved, because the composition of the mixture could be kept perfectly regular; whereas with coal-dust firing it was subject to uncontrollable variations, owing to varying quantities of ash from the fuel. Gaseous fuel must, however, be always more costly than coal-dust, because gasholders were needed to maintain a uniform pressure, and their introduction must be the cause of loss of heat. The cement produced by the rotatory process, even with coal-dust firing, was, for the reasons advanced by the Authors, actually of better quality than could be attained, as a rule, with the processes hitherto employed. Even if the specially favourable circumstances which, in America, had conduced to the attainment of a successful result in a comparatively short time, viz., the low price of coal and the high price of labour, did not obtain in other countries, or did so in a much smaller

[1] Protokoll der Verhandlungen des Vereins Deutscher Portland-Cement-Fabrikanten, 1900, p. 205.

Dr. Michaelis. degree, yet, apart from this, the whole process of manufacture was so much simplified, concentrated, and made independent of the will and skill of the workmen, that there could be no doubt the rotatory process would produce a cheaper and better cement in those countries also. The fewer the workmen needed in an industry the greater the certainty with which its operations could be carried on; and there was little risk of making a false prediction in advancing the opinion that in a short time this rotatory process would make triumphant progress over the whole world.

Mr. Rigby. Mr. J. S. Rigby had been acquainted with the working of rotatory furnaces for the past 30 years. When introduced into the alkali industry they had not been looked upon very favourably for a considerable time. Some works, after working with the "revolvers," had been unable to obtain the beneficial results expected, and had returned to the old hand-furnaces; other manufacturers who had struggled with the innovation had eventually made the revolving furnace a success, and the old hand-furnace had gradually fallen into disuse. This form of furnace was of much greater diameter than that used for cement, and instead of passing through it continuously, as in the case of cement, the decomposed lava-like material was discharged periodically as soon as the man in charge was satisfied that the proper stage had been arrived at. He had attempted to calcine cement in one of these furnaces but had found it unsuitable owing to the heat being insufficient. Some time afterwards he had met the late Mr. F. Ransome and had seen his form of furnace in operation on the Thames. This had proved the pioneer of the present system of burning cement in rotating furnaces as carried out in America, for Mr. Ransome had sold his American patent to an American who had devoted his capital and energy to securing for it the success which it had now attained in that country. As had been the case when revolving furnaces had been first introduced into England, the novel process had not been attended with any beneficial results for years; for during occasional visits to the United States he had called upon the engineers who had the business in hand and had learned of their uphill fight, and, from outsiders, of the thousands of tons of spoiled material lying about the new furnaces. Eventually their efforts had been crowned with success, and the highest quality of cement produced was made by rotatory furnace. This system of calcination would be found to commend itself especially to the makers of cement by the dry process; but in the chalk districts where the wet process was in general use, it might be found equally applicable, on account of the control that could be exercised, which would ensure a more perfect decomposition of the raw materials, and consequently a superior cement. With regard to the present system of firing, which was the only one that had been found to work satisfactorily —viz., with powdered fuel—this, to his mind, was the most expensive part of the process, and if a gas-producer, such as the Mond producer now working so successfully at the works of Messrs. Brunner, Mond & Company, could be modified, either in combination with a limited quantity of powdered fuel or in some other way, the cost of producing cement by the rotatory system would be reduced to a minimum. Mr. Rigby.

Mr. F. Schiele, of Giessen, had been much interested in the Paper, and had found mentioned in it, almost word for word, all the difficulties which his own firm had experienced and had had to overcome; and, on the other hand, the remedies which they had discovered in some instances agreed almost exactly with those mentioned in the Paper, although they had worked quite independently of American investigators. Immediately after he had taken over, in July, 1897, the management of the construction and working of the first cement-works with rotatory furnaces erected in Germany, at Lollar, the necessity for an efficient method of burning which would give a uniform high temperature, in order to obtain clinker of a good regular quality, had been evident. For this purpose only the method of coal-dust firing under pressure had been known, the working of which from the first had proved to be superior to other methods and entirely satisfactory. In his practice the burner consisted of a tube connected to a high-pressure fan and terminating inside the kiln in a broad nozzle which was capable of being moved vertically. The coal-dust was fed regularly into the stream of air by means of an apparatus which could be easily controlled from the burning-cylinder, and thus a uniform clinkering-temperature was maintained over a certain zone, the position of which could be altered at will by means of the adjustable nozzle. The consumption of fuel in the production of cement from blast-furnace slag and limestone, including that required for drying the raw materials, was, with uninterrupted working, materially less than the 30 per cent. of the weight of the clinker given in the Paper as the consumption for American conditions and the use of marl. With regard to the lining of the burning-cylinder, the material used for this purpose had, from the first, been one containing 35 per cent. to 40 per cent. of $Al_2 O_3$. In the course of the work the production of a clinker-like coating on the lining itself had been observed, and its exceedingly favour- Mr. Schiele.

Mr. Schiele. able effect on the durability of the lining of the clinkering-zone had been quickly noted. Accordingly subsequent operations had been directed with a view to the speedy production of such a protective coating. Like the salt used in the Hurry-Seaman process, the coating of finely-divided ash, formed on the lining of the kiln when first fired, softened the firebrick and facilitated the adhesion of the cement-material. For a considerable time past the practice of introducing ordinary cement-material in the first place had been given up, and, instead, the fine and more easily fusible material carried over into the dust-chamber of the kiln and there mixed with fine ash, had been used, which had proved to be preferable for the production of the desired protective coating. The success which under other circumstances might certainly have been looked for with this lining had not, however, been realised, as the kilns and the machinery connected therewith had been subject to frequent stoppage. The stresses set up by the cooling, owing to the different expansibilities of the three layers, viz., the firebrick, the cement-clinker, and the vitreous layer between them, of course caused continual detachment of the clinker-lining, which, in frequent alternation with its re-formation, must result in partial destruction of the firebrick beneath. The alterations necessary to obviate the mechanical difficulties had for some time been settled and were being carried out. The Authors had justly laid stress on the importance of the regular and uninterrupted working of rotatory furnaces, which was desirable not only in regard to output, but also on the ground of economy of fuel and preservation of the costly kiln-linings.

Mr. Simmons. Mr. W. H. Simmons remarked that decided changes had been made in the Bronson Portland Cement Company's method of manufacture since he had begun his duties as chemist to that Company early in 1900. The shale clay had been rejected as being too high in alumina, and a plastic clay had been found which was lower in that constituent by 30 per cent. of itself. Petroleum was no longer used as fuel, but pulverized coal, fed by a blast of warm air, had superseded it. The coal used contained about 9 per cent. of ash, but this, it was found, did not need to be considered in computing the mix of slurry. The fuel was very finely ground and was fed into the cylinder just above the centre of the end, and the resulting ash was nearly all carried through the cylinder, and fell into a pit just beneath the stack for gases. The Company had introduced a rotatory cooler, with a blast of air through it, which was very satisfactory, and the clinker, falling from the cooler into a wagon, was dumped into an elevator which carried it to the grinding-mills. By this method the expense of much handling was avoided. The clinker was sprayed with water as it passed along the pan conveyor from the rotatory kilns to the cooler. They still used magnesite bricks for kiln-lining, but found that these could be made to last much longer than formerly by the following method. When first starting a kiln, a slurry was prepared which was about 2 per cent. lower in lime than that which was usually burned. This, of course, burned at a much lower temperature than the usual slurry, and in the course of a few hours formed a coating over the brick. After the coating had been secured the temperature of the kiln could be raised, and higher-limed slurry could be burned successfully without in any degree injuring the brick lining. This lining or coating of clinker would adhere to the brick as long as the kiln was kept in operation, but if permitted to cool it would crack and scale off. Mr. Simmons.

Mr. CHARLES SPACKMAN observed that only two mills had been taken as typical of the cylinder-fired cement plant of the United States; the works of the Atlas Cement Company, representing the largest and most successful plant using the dry process, and that of the Bronson Cement Company, manufacturing by the wet process, the latter being generally considered to be one of the least successful of its type. In briefly reviewing the history of the introduction of the rotatory kiln into America, honourable mention should be made of the name of Mr. Pierre Giron, who had been the superintendent of the Atlas Company from its inception, and who, while the works were owned almost exclusively by Mr. Navarro, had so far perfected the Ransome process as to place it beyond the experimental stage and to produce a stable and high-quality Portland cement, burned with crude oil. Mr. Spencer B. Newberry likewise deserved credit as the pioneer of the rotatory process, employing wet slurry and burning with oil. In the works at Warners, New York, he had made use of a double set of rotatory kilns, one set being employed for drying the wet slurry and the other for the calcination of the clinker. For various reasons this plant had never proved a commercial success, but after his connection with this undertaking had been severed, Mr. Newberry had erected a small works at Bay Bridge, near Sandusky, Ohio, and there he had likewise employed two 40-foot cylinders with a double system as before. He had afterwards riveted together the two sections into a single cylinder, 80 feet in length, into which he had introduced the wet slurry. This had been done in 1893, but after many experiments he had become convinced that kilns of this length were quite unsuitable for the Mr. Spackman.

Mr. Spackman. process. Messrs. Lathbury and H. S. Spackman also deserved mention for their experiments in burning wet slurry in the Lehigh region. As early as 1895, Mr. Lathbury had been conducting a series of trials, extending over 4 months, at the works of the Alpha Portland Cement Company in the use of pulverized coal as a substitute for crude oil, which previously had been exclusively employed as fuel in all the rotatory kilns in America. These experiments had been successful, and the company had decided to put down a plant for coal-dust fuel. A mechanic employed at the Alpha Works had entered somewhat later the service of the Atlas Company, and rival patents for this process, applied for in the interests of both companies, had failed. The application of the Alpha Company had been, however, some 6 months earlier than that of the Atlas Company; priority of invention was claimed for both these concerns. No other cement-works had used pulverized coal until the completion of the Castalia Works in Ohio in 1897. There was now only one rotatory plant in the United States using oil fuel, and this was situated in California, where the price of coal exceeded that of oil. The works at Castalia were in the vicinity of those already mentioned at Sandusky. The Castalia plant, designed by Messrs. Lathbury and Spackman, comprised four rotatory kilns, 5 feet in diameter and 60 feet in length; the cement was manufactured by the wet process from a finely-ground mixture of coarse granular marl and blue clay, the fuel being pulverized coal. About the same time these gentlemen had been making experiments with the use of blast-furnace slag and limestone, in order to determine whether it was possible to burn these materials in a rotatory kiln and thus to produce a good quality of Portland cement. These experiments had ultimately proved successful, and in the early part of 1898 works had been started for the Clinton Cement Company, connected with the Clinton Iron and Steel Company in Pittsburg, Pa. Although the total output of suitable slag was but small, the cement produced, ever since the works had been completed in the autumn of 1898, was quite undistinguishable from Portland cement of the highest quality. The raw materials were burned in cylinders in a dry state with pulverized coal. The slag was subjected, previous to drying and grinding, to a thorough washing during granulation, in order to free it as far as possible from the sulphur compounds. The limestone mixed with the slag was that originally supplied to the Bessemer furnaces, and contained about 95 per cent. of calcium carbonate. About the period of the completion of these works

Mr. Spackman.

the same engineers had designed and started a plant of their own at Wellston, Ohio, in order to manufacture cement from limestone and clay by the dry process, using pulverized coal. These works, known as the Alma Portland Cement Company, which at the time of their establishment had evoked considerable adverse criticism in respect of the process adopted, had been in successful operation for 3 years. It had been asserted by experts that limestone and clay could never be burned together in cylinder-kilns in a dry state, as a separation of the two ingredients would necessarily follow when subjected to the full blast, but this opinion had been proved to be entirely erroneous in practice. Messrs. Lathbury and Spackman had likewise designed plants at the Michigan Alkali Company's works for the production of Portland cement from soda-waste and clay, and a small factory at Milton, North Dakota, to produce cement from calcareous earth. Some interesting experiments were also in progress under them as to the use of different kinds of coal in the cylinders, the governing factor being of course the percentage of ash; the sulphur had not proved in any way troublesome. Certain kinds of coal, owing to the amount of ash, had tended to increase the percentage of silica in the product so greatly as to render their employment impossible. During the past winter Messrs. Lathbury and Spackman had been testing at their factory, on a commercial scale, coal, limestone, and clay brought from Japan; the results had proved excellent, the coal especially being equal to the best descriptions found in America. The majority of the rotatory-kiln plants in the United States worked their grinding-department for clinker, as well as their kilns, on Sundays and holidays. Although there were several cement mills in which cylinders 60 feet in length were employed, having two different diameters (6 feet for the front and 5 feet for the rear end), nearly all the kilns now constructed were of this length, but with a diameter of 6 feet throughout. The inclination of the kiln varied considerably, in accordance with the nature of the raw materials in use. Cylinders in which marl and clay were treated by the wet process were generally set at a gradient of ½ inch to the foot; while in the case of the argillaceous limestone of the Lehigh region, used in a dry state, an inclination of between ¾ inch and ⅞ inch per foot was found best. The speed at which the kiln was driven varied with the inclination and the nature of the materials, but it should be under the complete control of the burner, and the best results were obtained by using speed-regulators (cone reduction-apparatus) on the driving gear for both kiln and coal-feeds, so that the burner

Mr. Spackman. could change these details at will. In the majority of rotatory kiln-plants at the present time the coal was dried either in rotatory dryers or in some form of tunnel. The cylinders for coal-drying were commonly 40 feet in length and 4 feet in diameter. They resembled the kilns, but were used without a lining. Instead of forcing in pulverized coal, an ordinary fire-box was applied at the discharge-end, and the hot gases passed through the rotatory dryer into the chimney-shaft at the far end. There were, however, two small plants in which the coal was ground in a high-speed centrifugal hammer disintegrator, sufficient air being provided by the revolution of the hammers to force the coal-dust directly into the cylinder, and one such machine being installed directly in front of the discharge-hood of each kiln. Though this plan had several disadvantages, it was said to involve only one-third the cost of an installation of rotatory drying-plant and tube-mill grinding-plant for the coal, but it was rather wasteful of fuel. Nearly all the principal manufacturers first reduced the coal in a rough crusher or disintegrator and then passed it into tube-mills to be ground with flint pebbles. The earlier works employed the Griffin mills, and the Atlas Company, who owned and controlled the Huntington mill, were the only users of that form of grinding. The best results were no doubt obtained by the use of tube-mills. Very great attention had been directed by cement-makers to the subject of kiln-linings. Excellent results had been obtained by the employment of a special firebrick, consisting of about 41 per cent. of silica and 49 per cent. of alumina; as this was but slightly acid, owing to the high alumina contents, it avoided the risk of fluxing to which the Authors had alluded. The analysis given in the Paper represented a class of firebrick certain to give rise to continual difficulties. Experiments had been made as early as 1894 to produce linings for the cylinders consisting of bricks compounded of a mixture of cement-clinker, ground to pass a $\frac{1}{4}$-inch mesh, and Portland cement. The results, however, had not been wholly satisfactory. The method of covering the bricks with a protective coating of clinker, as described, was not generally followed at the present time, but skilful burners could coat the bricks with a deposit of molten slurry, which subsequently served the same purpose. The employment of magnesia bricks, formerly used for cylinder-kilns adapted for the wet process, had been totally abandoned, chiefly because the bricks were found to shrink in use and speedily fell out of their places. Many plans were practised for the regeneration of the waste heat from the clinker; one of the most successful

Mr. Spackman.

depended upon the use of masonry vaults placed directly underneath the discharge-hood of the kiln. These vaults had sloping floors, outlets from which opened into a tunnel. Cold air was forced from the lower level of the vaults, and, passing thence through the pile of hot clinker, it became heated so that it could be drawn off and forced back into the kilns, mixed with the pulverized coal. The use of a jet, spraying water upon hot clinker, was quite unnecessary if the raw materials were thoroughly mixed and pulverized and the clinker was properly burned. At the best it was only a makeshift, and the process was not now carried out in any of the leading works; the few makers who had once tried it in America had in most cases abandoned it. In the matter of fineness of grinding, the following tests could be imposed:—20 per cent. residue on a 200 × 200 mesh sieve; 5 per cent. residue on a 100 × 100 mesh sieve. The Authors, in their estimate of the cost of manufacture per ton of cement, appeared to be somewhat low. It was not now possible with the best descriptions of cylinder-kilns to turn out cement at less than 60 cents per barrel of 380 lbs., say $3 54 cents for 2,240 lbs. The cost of the rotatory process for wet slurry was greater than would be the cost of burning the same material in vertical kilns of the Schoefer type, owing to the increased consumption of coal. The Authors did not seem to be well informed respecting the high efficiency and the standard of excellence attained in plants other than that of the Atlas Company. Among these might be mentioned the works of the Lehigh Portland Cement Company at Ormrod, Pa., using materials similar to those employed by the Atlas Company and burning dry. This plant had two separate mills, with a capacity of 4,000 barrels a day. There were several rotatory plants, among which were the Saylor (3,000 barrels per day), the Alpha (2,500 barrels), the Vulcanite (2,000 barrels), and the Lawrence Company, Pa. (1,500 barrels per day), all using argillaceous limestone, which could show cost-sheets as low as, if not lower than, those of the Atlas Cement Company. As regarded the method of handling coal, it was quite true that fans were commonly employed, and they could be used with good effect. Only one other company was now using compressors, namely, the Virginia Portland Cement Company, of Craigsville, Va. By both of these systems a proper control of the temperature could be insured, and the fans were much less costly in use. Producer-gas had been found to give poor results, but natural gas was being employed at the works of the Iola Portland Cement Company, in Kansas, as adapted to a cylinder-plant. The entire machinery of these works was operated by

Mr. Spackman. gas-engines, and the undertaking was being followed with great interest by cement-manufacturers, as the cost was at least 30 per cent. lower than that at any other cement-works in the country. In the case of slurry plants, although it was customary to line the cylinders with firebricks throughout their length, there was nothing to be gained by employing the lining all through the kiln. Good results were being obtained from 60-foot kilns with a lining 9 inches in thickness for two-thirds of their length; the heat at the rear end not being sufficiently intense to buckle the steel plates. There was a general consensus of opinion in America that the prolongation of the cylinder-kiln for the production of clinker from slurry was entirely unsatisfactory. The Authors had been misled in their statements that practice had demonstrated that there was the same coal-consumption both with dry and with wet materials. For the former the coal needed was about 25 per cent. to 30 per cent. on the weight of clinker produced, and for the latter it ranged between 40 per cent. and 45 per cent. on the weight of the clinker. The reason that long cylinders operating on slurry failed to give satisfactory results, both in production and in coal-consumption, was, as careful experiments had demonstrated, that within 10 feet of the point at which the slurry entered the kiln, the moisture was entirely driven off. Samples taken at intermediate zones 5 feet in length showed little change in the chemical or physical condition of the raw material up to a point within 25 feet of the head of the kiln, or 35 feet from the rear end. At this point the carbon dioxide began to be expelled, whilst the real clinkering took place within a zone extending 15 feet from the fuel pit. When the kiln was lengthened beyond 60 feet, the temperature of the waste gases was correspondingly reduced towards the rear end of the cylinder and tended to reprecipitate the moisture in lieu of carrying it off into the chimney. There were no mechanical difficulties in supporting or in providing for expansion in the use of a kiln 90 feet or even 100 feet in length, but such kilns were of little or no practical use. For many of the foregoing statements, he was indebted to Mr. Lathbury, whose opinion on these processes was of high authority in the United States.

Mr. Stokes. Mr. WILFRID STOKES remarked that the Authors scarcely gave the credit due to Mr. T. R. Crampton, who in 1877 had proposed a rotatory cement-kiln in which the raw wet material was to be burned to clinker by the adoption of a powdered-coal burner in a long revolving cylinder. Several inventors had proposed to burn cement in a revolving furnace, but the method proposed by Mr. Crampton was the nearest to that now found most successful.

Mr. Stokes. There was nothing novel in the furnace used by Mr. F. Ransome, and the theory of the process was of course quite wrong; the inventor, however, should have credit for having induced various makers to try his scheme, as out of one of these attempts with liquid fuel, in America, had grown the results which the Authors had so clearly set forth. Looking back at the efforts which he himself had made with his own process in 1893, it was interesting to see how near to success he had arrived. The lining of the burning-cylinder had been the great trouble, but had powdered coal been used, the variations in temperature incidental to heating by producer-gas would have been avoided, and the lining would have lasted very much longer without repairs; as the bauxite bricks, which with great difficulty he had been able to make, had been sufficiently basic not to flux with the clinker. The key-note of success with any revolving cement-furnace was the lining, and the very simple method adopted by Messrs. Hurry and Seaman seemed to have solved the problem effectively. He could not but think, however, that the process as a whole was more complicated than it need be, and that the first cost of the apparatus must be a not inconsiderable item when estimating the cost of production. He noticed that the Authors omitted all mention of interest on capital, depreciation, etc., in their comparative estimates. It would be very instructive if this information could be added. It was not at all clear that slurry could not be washed sufficiently fine to give a clinker which was devoid of free lime, and with suitable apparatus the extra cost of washing would amount to very little. It would seem a sounder policy to guard against the presence of free lime in the burnt clinker than to provide means of making it harmless as in the Hurry-Seaman plant.

Mr. Thwaite. Mr. B. H. Thwaite observed that the Authors had demonstrated that, once again, American enterprise, perseverance and prescience had brought into practical use industrial processes invented by Englishmen. The main credit for this process was undoubtedly due to Mr. Frederick Ransome, and the Authors did Mr. Ransome injustice in saying that it had been his real intention in introducing this process, to avoid the necessity of grinding. As he had been associated with that gentleman in some of his early experiments, his impression was clear that Mr. Ransome had expected that the fusion effect would produce very small granules of cement clinker, requiring comparatively little grinding. Mr. Ransome had had another object in view, viz., to avoid the introduction of ash, or any portion of the incombustible residue of the fuel, into the raw materials for producing cement. By his employ-

Mr. Thwaite. ment of gaseous fuel he had been able to do this; but, unfortunately, the temperature obtainable from the combustion of this fuel without recuperation had not provided the temperature necessary to effect continuously and in a perfect degree the object desired. The difficulty in applying recuperation had been, as the Authors had stated, the prevention of the incursion of dust into the recuperative chambers. The maintenance of the integrity of the cylinder-lining, and especially that of the projecting bricks, had been another great difficulty, the bricks having a tendency to break off. The object of the projecting bricks had been to raise the powdered mixture to such a height that it would fall, rainlike, through the flame; then there had been a difficulty in preventing the lime from combining with the silica contents of the lining bricks, which, along with the clinker, had a tendency to form aggregations that seriously impaired the efficiency of the system. Mr. Thwaite had tried the employment of powdered, instead of gaseous fuel, some 11 years or 12 years ago, but the results had not been encouraging, the heat-production having been too intense and too local. He had always urged upon Mr. Ransome the necessity of employing water-gas, or other gas of higher calorific value than ordinary producer-gas; because it had been soon realised that the low calorific character of ordinary producer-gas would be a fatal defect, unless the latter were combined with the recuperative method, and this latter combination had been hitherto found to be impracticable. He had recently devised a method that would permit recuperators to be used. The use of oil had been alluded to, but the cost of this fuel in England made it commercially impossible. From his experience of Mr. Ransome's apparatus, he had arrived at the conclusion that the process would require to be effected in two or more stages or cylinders, acting in series, each cylinder being independently controllable both as to speed and nature and intensity of combustion employed; and it was obviously necessary for economic reasons to recover the heat of the gases flowing from the high-temperature cylinder, constituting the final stage of the process. He had therefore invented, so long ago as August, 1887, a process in which two cylinders were employed, and which was fully described in the specification of the patent.[1] The cement materials were fed into the upper end of the low-temperature cylinder, and gravitated through it, falling into a chamber from which they were fed into the high-temperature cylinder, where the heat was sufficient to produce cement-clinker. The gases

[1] 1887. 22 August, No. 11,412.

Mr. Thwaite.

from the high-temperature cylinder (which was lined with fire-brick) flowed through the low-temperature cylinder, which was unlined; means were provided to add a supply of heat, when required, to the first, or drying, process in the low-temperature cylinder, and recuperators permitted the air to be heated to increase the temperature of combustion. This design practically covered the arrangement successfully carried out in America, and he might observe that the patent granted for the Stokes apparatus was dated 10 July, 1888. A later arrangement of this type of furnace had been designed and patented by Mr. Thwaite in association with the late Mr. Thomas Denny,[1] and applied for the purpose of calcining the highly refractory conglomerates (auriferous) of the Southern Transvaal, and the gas-fired furnaces erected near Vryheid had been very successful. There were three conically-shaped cylinders of different diameters placed one above the other and possessing independent rotating gear, as well as supplies of air and gas under pressure. The materials to be calcined were raised by elevators into the top cylinder through a forged, water-jacketed pipe, having an internal screw so as to produce positive feeding effects. The air-supply was fed by a Thwaites blower, the air being distributed to the furnace through perforated blocks supplied at each stage. The system proved to be completely under control. The rollers carrying the furnace had chill-hardened surfaces, and were provided with adjustable bearings to permit of adjustment for wear. As the furnaces rotated on horizontal axes they worked more evenly than did inclined furnaces, and there was less difficulty in forming a satisfactory joint where the ends of the cylinder entered the brickwork of the vertical shafts. This furnace was an ideal one for cement-production, the only necessary alteration for this purpose being the elongation of the cylinders. The system adopted by Messrs. Hurry and Seaman for preventing the adherence of the cement-clinker to, and the fluxing of the lining, was a valuable one, and removed at once one of the difficulties associated with rotatory Portland-cement kilns. He was, however, in possession of details of a method of surface-treatment of ordinary refractory bricks which rendered the latter not only indestructible under the influences of the highest temperatures required for every-day industrial purposes, but also proof against ordinary basic or acid influences at temperatures below 4,000° F. This new surface was produced by the melting

[1] 1892. 23rd August, No. 3922, New South Wales.

Mr. Thwaite under the influence of the electric arc of a mixture of carborundum and a special paste. The fused mass was applied, for a depth of $\frac{1}{8}$ inch, to the surface of the firebrick which was to be exposed to heat and chemical influences. There was no doubt that this system would serve the same purposes as that introduced by Messrs. Hurry and Seaman. From the analysis of the coal used at the Atlas Works given by the Authors, it appeared that there was 8·38 per cent. of ash. He would like to know what proportion of this ash was found to be combined with the cement-material. If the Authors could provide an analysis of the products of combustion, they would add considerably to the value of their Paper. He was under the impression that the intense localization of the combustion (inevitable with powdered coal, except with excessive air-blast pressures or steam injection—both remedies involving a loss in heat-efficiency) would tend to destroy the firebrick lining. He would also like to know how often the cylinders had to be stopped for the renewal of the linings. The Authors had omitted to mention the name of Mr. David Wilson, a practical cement-manufacturer, who had sacrificed both money and time in attempting to prove the practicability and economy of the Ransome rotatory kiln. They were to be congratulated on having raised the subject of rotatory kilns and on having dealt with it in so thorough a manner.

The Authors. The AUTHORS, replying to the Correspondence, wished to point out that some of the writers had hardly appreciated points which were clearly set forth in the Paper. Such were the percentage of fuel needed in fixed kilns of the shaft type, which could not be considered without taking into account the quantity needed for previously drying the raw materials; the endurance of the firebrick lining when perfectly protected by a coating of clinker; and the consumption of coal-dust with wet raw materials computed from thermal data and corroborated by practice; also in some instances correspondents had failed to realize that the economy of working of the Hurry-Seaman process was not derived from a mere estimate but from the actual working cost for an output of many thousand tons. They would refer individual contributors whose communications were not dealt with in detail to the facts already at their disposal. They had read with much interest Mr. Candlot's remarks and agreed with him that in most American works the amount of fuel used was extravagant; in the process carried out at the Atlas Works the consumption seemed still extravagant when the actual quantity of heat needed was taken as the standard; nevertheless it was reasonable compared with the 60 per cent. cited by Mr. Candlot, being indeed only 30 per cent. Mr. Candlot was mistaken in supposing that a particular quality of coal was needed for the rotatory process, or that the proportion of ash was of importance except as diminishing the calorific value. His estimate of the saving to be effected by a well-conducted rotatory process was much below the mark, the reason being that those rotatory processes which were public property were not particularly well devised and were by no means systematic, whereas the Hurry-Seaman process, of which the Authors had made a somewhat close study, possessed both these qualities. They took this opportunity to say that though the rotatory process was sound in principle, its application took many forms which were far from economically acceptable in practice. In their Paper, with a knowledge of every typical rotatory process, they had selected one which in their opinion most nearly approached a good standard of efficiency, and their statements of cost were based on this and not on the results obtained by imperfect application of the same general method. The Authors.

Mr. Carey might dismiss from his mind the idea that the results of the rotatory process in American practice were not easy of attainment under English conditions. They were glad to see that he was a believer in the advantage of the rotatory method, and they would have been pleased to supply him with information concerning the Hemmoor plant had they been free to do so. They concurred that there were no patent rights in rotatory kilns as such, but there were important patent rights in the arrangement of the kilns and in the methods of firing them and handling the product. They must dissent altogether from his view that the old plan of plastering fixed kilns with slurry had anything in common with the systematic and controllable coating of rotatory kilns with clinker; the latter procedure had been fully described in the Paper. Moistening clinker in a haphazard and ineffectual manner had been practised for many years, but regulated and effective moistening was a modern development. The old process was largely directed to quenching silicates which would otherwise have "fallen," and was conducted without proper knowledge of the true advantage to be obtained. Moreover, clinker in large lumps did not lend itself to systematic sprinkling; it was only well made rotatory clinker which was capable of absorbing and utilising the regulated proportion of water applied on it. The figures given in the Paper as to cost of production, criticised by Mr. Carey, were taken from actual records of important works; they were in no sense arbitrary figures or mere estimates. The

The Authors. Authors, therefore, though freely admitting that local circumstances might cause increase or decrease of items going to make up the total, were of opinion that the cost given might be taken as an accurate guide under average conditions. With regard to his observations concerning the item "raw materials delivered at the mill," it did as he surmised include the labour for getting and delivering the raw materials, but not for drying. Mr. Carey's estimate for fuel was for steam-coal; the powdered coal used in the kilns was not steam-coal, but a cheaper grade of fuel, and the Authors' figures took account of this. The cost of fuel stated included that requisite for grinding the coal and for all necessary drying-operations.

Mr. Charles Erith's questions were answered by implication or explicitly in the Paper itself, or in the replies to other speakers or correspondents. His information concerning the rotatory process was evidently drawn from those imperfect forms which had done much to impede its introduction into this country. The Authors were indebted to him for pointing out that difficulties of working which might be encountered in the adoption of the rotatory process could be met by "highly skilled mechanical management, as usual in America." It was this highly-skilled management which they desired to see introduced into this country to bring about the abolition of those antique and wasteful methods which they condemned equally with him.

The kilns mentioned by Mr. Goreham, which were composed of vertical cast-iron segments, were fixed kilns and in no way comparable with rotatory kilns. This mode of construction, as stated in the Authors' reply to the discussion, was not applicable to rotatory furnaces. The price and expenditure of fuel touched on by Mr. Goreham had been dealt with in their reply to Mr. Carey. Mr. Goreham had quite correctly said that cost of manufacture was the all-important question, assuming the quality of the cement to be equal in all cases. It was this question of quality which made comparison between different processes difficult. It was an easy matter to turn out a large quantity of material which might be described as cement from kilns of the most imperfect type with a surprisingly small consumption of fuel, but the Authors did not think that such cement would satisfy the reasonable requirements of engineers. The quantity of underburnt material from many kinds of fixed kilns was surprisingly large, and it was a regrettable fact that in most cases the whole of this dangerous rubbish went into the crushers. In the Authors' opinion it was not the least advantage of a well-contrived rotatory process that these irregularities ceased; that the product was uniform, uniformly burnt

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and uniformly sound. Picking was impracticable, but it was also unnecessary. Without wishing to be dogmatic they thought it justifiable to assert that only those who were familiar with really good rotatory clinker were competent to pass an opinion on what constituted evenly burnt material; the ordinary easy standard of quality was superseded.

In reply to Mr. Walter Hewitt, the Authors could state without reservation that no system of slaking, however elaborate and well-devised, could render unnecessary the most vigilant care in the mixing and grinding of the raw materials. The real utility of the system of slaking which they had described lay in the fact that however carefully mixing and grinding were performed, yet under ordinary works conditions even rotatory clinker might contain some unsaturated lime compounds. These were slaked and rendered harmless, greatly to the improvement of the strength and soundness of the cement. The present system of air-slaking, though useful, was a makeshift and would be superseded when the principles on which it depended were more generally understood.

The Authors were indebted to Mr. H. le Chatelier for his interesting data concerning the expansion of magnesia bricks. The defects on which he commented had doubtless contributed to difficulties experienced in utilising these bricks for cement-kiln linings. Happily, by the adoption of the method of protecting common firebricks described in the Paper, the need for employing magnesia bricks had ceased. Mr. Macoir had fully realised the causes of the success of the Hurry-Seaman process; its comprehensive system, its continuity, its automatic operation were factors as potent as were its novel methods of burning, cooling and protecting the kiln-linings. Those European manufacturers who, like Mr. Macoir, had this clear understanding of the essence of the subject would not be slow to secure economy by a wholesale modernization of their plant. Mr. William Matthews, as an engineer responsible for work in which an enormous quantity of cement was used, naturally hesitated to abandon the existing method of air-slaking before he was convinced that by the new process a similar improvement could be secured. The limited hydration necessary for slaking unsaturated lime compounds could be attained in a variety of ways, of which air-slaking was one. The Authors were of opinion that systematic and controlled moistening of rotatory clinker was a more effective and reliable method, and if properly conducted would abolish the necessity for air-slaking. It was of course to be understood that the clinker was properly and uniformly burnt; it was no use

The Authors. attempting to pick a batch of bad clinker if by some accident such material was produced; it must be reburned or rejected altogether. The presence of clinker of this class would certainly be detected by rigorous tests for soundness. Therefore, given a competent and honest manufacturer and proper examination of the finished cement, no hesitation need be felt in dispensing with the present method of aeration and turning. The Authors preferred the ratio established by Mr. H. le Chatelier to that proposed by Dr. Michaelis. There was no evidence that silicates, aluminates and ferrites containing 2·5 equivalents of lime to 1 equivalent of acid oxide existed, whereas tri-basic compounds had been actually prepared. In their own experiments they had succeeded in attaining the ratio $\frac{CaO}{SiO_2+Al_2O_3} = 3$ very approximately, and cement of this composition had been perfectly sound. In ordinary industrial cements the approximation was less close, but that was no reason why a correct ideal should not be maintained. Dr. Michaelis himself had shown the way in his researches on the properties of fused clinker, and it might well be that in the future all cement materials would be run down to an actual slag. The rotatory process would then disappear and would be replaced by an operation conducted in an apparatus of blast-furnace type. Mr. Hurry's experiments were now directed to this end. The Authors, some 10 years ago, had experimented with lining-bricks made of Portland cement, and were of opinion that such bricks had many merits. But to be perfect they needed to be considerably more basic and less fusible than ordinary Portland cement, and the difficulties in preparing them were great. Until success had been attained, a practical evasion of the difficulty was afforded by the Hurry-Seaman method of providing a plastic clinker coating. The use of gaseous fuel, adverted to by Dr. Michaelis, possessed theoretical advantages, but in practice it was found that, contrary to expectation, the ash of the solid fuel (coal) contributed but little to the clinker; it chiefly passed through the kiln. The Authors had had the advantage of seeing the process at Lollar, near Giessen, described by Mr. Schiele, and were glad to learn that the fuel-consumption had been materially reduced. It must be remembered, however, that a large part of the lime in the raw materials was not as carbonate, but in the form of blast-furnace slag, and thus the quantity of heat needed was substantially decreased. The difficulty experienced by Mr. Schiele in protecting the firebrick lining was not without parallel, as was shown by the following extracts (translated) from a Paper by Dr. Valur of Hemmoor (where a similar process was worked) read before a meeting of

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the Association of German Portland cement manufacturers held in Berlin in February, 1901 :—

"I come now to the repairs, and I must admit that, during the past year, the firebrick lining of the kiln has caused us much inconvenience from stopping the running, and has put us to considerable expense, We found that the firebricks in the clinkering zone required to be renewed every 6 or 7 weeks, in spite of the fact that we tried two different kinds of brick and made the lining of various thicknesses, *e.g.*, 20, 25, and 40 centimetres (about 8, 10, and 16 inches respectively). The average cost of repairing was 700 marks (about £35), so that for the year 1900 our repairs bill was about 5,000 marks (about £250), corresponding with 14 pfennig (1·68 penny) per barrel of cement produced."

After alterations of the method of burning—

"The rate of wear of the firebrick lining was very small, viz., about 1 centimetre in a fortnight. Therefore, if we assume that a lining 30 centimetres thick is used, and that it can be run until it is only 5 centimetres in thickness, it follows that repairs will have to be effected twice a year, at an annual cost of 1,400 marks (about £70).

"Taking the output of the kiln at 60,000 barrels a year, the cost of repairs to the firebrick lining works out at 2·3 pfennig (0·28 penny) per barrel."

It would be seen from these passages that even with the improvements effected, and in spite of the use of selected and expensive firebrick, the corrosion was considerable. The difficulties here described had been wholly overcome in the Hurry-Seaman process, which, using a cheaper form of firebrick, was nevertheless capable of protecting it so completely that the original firebrick lining was intact after 2 years' use.

The Authors were glad to hear of the improvements effected in the Bronson Company's process since their visit, and congratulated Mr. Simmons on the success which he had attained.

Mr. Spackman's communication was interesting as giving a history of the early struggles of American manufacturers to devise a workable rotatory process. He was, however, misinformed concerning the lining question, which, in the Authors' opinion, was one of the chief determining factors in the successful operation of rotatory kilns. The firebricks he advocated, containing a high percentage of alumina,[1] only served slightly to delay, and not to prevent, the destruction of the lining. The common firebricks, of which they had quoted an analysis, so far from giving trouble served perfectly when properly protected by clinker; the merits and defects of magnesia bricks had been dealt with by Mr. H. le Chatelier and in the Paper. The regeneration of the heat of the clinker, though desirable, was not essential to the economy of the process, because the clinker contained only a trifling portion of

[1] 49 per cent. is probably an error; no ordinary aluminous firebrick contains so large a proportion.

The Authors. the total heat necessary for burning (about 1 to 2 per cent.); many elaborate efforts had been made to pick up this heat by inventors ignorant of thermo-chemistry. The process of systematically moistening the clinker had already been sufficiently dealt with; it was a useful stage of manufacture and certainly not a makeshift. The Authors were well acquainted with the practice in other American works, but had selected the Atlas Company's works as most completely illustrating modern and rational methods. That they were warranted in this belief was sufficiently shown by the fact that whereas Mr. Spackman put the cost of manufacture in rotatory kilns at 16*s.* per ton of 2,240 lbs., the actual cost at the Atlas Works was not more than 12*s.* 6*d.* per ton. The high consumption of fuel in burning slurry (40 to 45 per cent.) alluded to by Mr. Spackman probably arose from the fact that the kilns with which he had experimented were unduly short. With a kiln of ample length, as shown in the Paper, there was no difficulty in reducing the consumption to 30 per cent., the same proportion as was needed for dry raw materials according to present methods; this figure was not merely deducible from the calculations which they had made, but had been reached in practice. The Authors were fully alive to the interest and importance of Mr. Crampton's inventions, but had been unable to find any record of their practical application; thus they had been constrained to forego their discussion. They heartily wished that Mr. Stokes had completely succeeded in his ingenious and persevering efforts, and that their Paper had been a description of English rotatory practice. Mr. Thwaite had apparently not bestowed sufficient attention on the text of Mr. Ransome's patent of 2nd May, 1885, which was set forth in the Paper. Nothing could be clearer than that Mr. Ransome supposed that the grinding of the burnt cement material could be dispensed with and in this he was in error. Mr. Thwaite's difficulties in the use of powdered coal had been completely overcome; the heat was not too intense nor too local, and by the use of well-designed burners it could be regulated to a nicety. His description of his endeavours to improve Mr. Ransome's original and ingenious process was historically interesting; in modern practice the elaboration of independent cylinders, recuperators, and the like, had been rendered wholly unnecessary. More details concerning the protective coating, consisting of a mixture of carborundum and a special paste, would doubtless be welcomed by members of the Institution. No sensible portion of the ash of the powdered coal remained in the finished clinker. The other points raised had been dealt with in the Paper.