Mr. ANDERSON said, a report had been spread abroad that the results obtained were due to the use of sulphuric acid, which, it was well known, had the effect of converting crystallizable sugar into uncrystallizable. In an early stage of the investigation of the new process, experiments had been made to ascertain if sulphurous acid affected cane-juice like sulphuric acid. Canes were obtained from Egypt, and the juice expressed in England. A certain quantity was clarified by the ordinary lime process, and an equal quantity by the sulphurous acid gas method. Both were submitted to analysis, and the result was that the latter gave a slightly higher result in crystallizable sugar than the former.

Mr. REDMAN observed that sugar was likely to become a large staple produce of the Australian colonies. The type of sugar-machinery hitherto used in the West Indies had been but slightly varied from, and he believed that described in 'Ree's Encyclopædia' nearly applied to the mills of the present day. The cane was crushed by horizontal or vertical rollers. About thirty-seven years ago he was resident in Barbadoes, where one class of machine was universally used, driven principally by wind-mills. The subsequent manipulation was very simple, compared with the elaborate processes described in the Paper; but he thought the manufacture, from that day to the present time, had hardly been improved. There had been a number of patents taken out for improvements in this class of machinery, of which the Messrs. Blyth of Limehouse, he believed, were the largest manufacturers, especially for the West Indies and the Isle of France; and the crushing-mills all possessed three cylinders, either horizontal or vertical. The horizontal cylinders were preferred at the time he spoke of. The principal difficulty hitherto had been in regulating the space between the cylinders for crushing the cane, and feeding them properly. Several patents had been taken out with that object in view, using adjustable gear, to vary the distance between the axles. These engines were frequently strained by overloading them with cane, by which the framework was liable to be broken; but various improvements had been effected in the supporting frames. He believed one person had enrolled a patent for converting the cane into what he termed sawdust, by sawing it with circular saws and then passing it through the cylinders.

In the West Indies, the period of raising the crop of sugar-cane varied from twelve months to fifteen months, the canes being planted during the rainy season; but some cultivators advocated cropping at an earlier period. The question of raising the crop on

sugar-estates in South Australia was one of great importance, and those who engaged in this occupation found to their cost, in the districts of Queensland and Brisbane, the canes were fatally affected by intermittent frost. In Egypt, he believed the cane was raised and harvested within a period of nine months. The question was, whether by irrigation or planting sufficiently early, there was a possibility of raising the crop in Australia before the period of frost commenced. He knew several estates that had been laid out for sugar cultivation which were now being discontinued as sugar estates, and were being converted into grazing tracts.

Mr. ANDERSON said the simplest way of regulating cane-mills was to make the engines powerful enough to perform about three times the average work brought upon them, and they would then surmount any obstacle. He had seen canes go over the top roller, when the mills were fed too fast, without any harm being done; but for such treatment the machinery must be sufficiently strong.

Mr. J. SHEARS noticed that the Author had not stated the percentage of juice obtained. The machinery at Aba was ingenious, but the rollers were unnecessarily large. The prime necessity in a sugar-cane mill was an apparatus sufficiently rigid to extract the whole of the juice available for sugar. Nearly all sugar-mills were now driven at a uniform rate at the periphery; and whether the rollers were 4 ft. in diameter or 30 in. in diameter, if rigid, no more juice would be extracted by them in one case than in the other. He assumed that a mill with rollers of 30 in. or 32 in. diameter was sufficiently rigid to extract all the juice that could be obtained. The sugar cane contained about 80 per cent. of juice which was of service to the sugar manufacturer; a further extraction of the waxy part of the cane interfered with the clarification, and impaired the subsequent operations. Therefore, if a mill of a certain length could produce with a smaller diameter of roller as much juice as one of larger diameter—and if, as was the case, less power would be required to drive it—much of the first cost of the machinery might be saved, and there would be greater economy in making the sugar. On the whole, he thought the Author had made the rollers of an extreme size.

When one of the vacuum pans in use at Aba—in which he was interested as a manufacturer—was tested on the 25th of January, 1871, he believed that Mr. Anderson rather expected to see it collapse under pressure. The exterior surface was about 200 superficial feet, upon which there was a crushing power of about 167 tons; the copper was only about $\frac{1}{4}$ in. thick. It was not surprising that those who were unacquainted with the tough nature of the material should think

the vacuum pan would collapse under such a pressure. The pans were proved under a vacuum, obtained by first putting a small quantity of liquor into them, and then heating them with steam; a vessel containing about 300 gallons of cold water was next hung up over them, and when the pans were well heated, and the steam sufficiently blowing through, every valve and cock was closed except one, by which the 300 gallons of water trickled into them, and a vacuum was produced. In one case, when the cock was closed, a vacuum was attained equal to 26½ inches of mercury, which was maintained for several hours. The vacuum was observed during three successive days. Twenty-four hours afterwards, the vacuum shown by the mercurial gauge had only gone down to 17 inches, and on the following day to 14 inches, the decrease being at the rate of only 0·125 of an inch per hour. It then became necessary to break the vacuum, to take the pan to pieces for shipment; and he calculated, if the vacuum had been allowed to expend itself, nearly eight days would have elapsed before the atmospheric pressure would have been attained.

Mr. G. PHILLIPS, through the Secretary, said that he considered the modes of producing and refining sugar detailed in the Paper to be radically wrong. Sulphurous acid gas as a bleaching agent of caramel in a sugar solution was detrimental, while, on the other hand, pure animal charcoal was capable of defecating and decolourising the lowest description of sugars, molasses, and treacle, in a few minutes.

The greatest difficulty had been experienced in introducing the various improvements which had already been adopted. He would instance the vacuum-pan. Howard, the inventor of this valuable aid to sugar-refining, nearly ruined himself, and some of his friends also, in his endeavours to perfect the apparatus, and, when perfected, had the greatest difficulty in effecting its introduction; the sugar-refining trade systematically opposing it. For some years, five London houses held their own on the old plan, by stating that their 'refined sugar' was not 'steam sugar;' and, as some portion of the public refused to use the so-called steam sugar, the houses in question flourished for a limited period; but when the public became enlightened the vacuum pan came into general use.

The centrifugal machine might also be cited. The elder Mr. Finzel—father of the present Mr. Finzel, the large sugar refiner at Bristol—invented the centrifugal machine for drying sugar crystals. Here, again, as in Howard's case, the sugar refiners refused to adopt so valuable an invention, and during the term of the patent only

two licences were granted. Mr. Finzel, however, being a sugar refiner, worked his own invention, and realised a large fortune by it.

The introduction of non-porous moulds afforded another illustration. Formerly porous moulds were used for crystallizing; the loss of sugar, in consequence, was something considerable. The non-porous moulds were rigorously opposed, on the plea that porous moulds favoured crystallization; but this invention having truth on its side, like Howard's vacuum pan and Finzel's centrifugal machine, ultimately made its way.

Other instances might be named; but the preceding were sufficient to show the dead weight that had to be moved, in the shape of ignorance, prejudice, and vested interests, in introducing an invention, however valuable it might be, to a stereotyped trade.

It was stated that 400,000 tons of sugar were refined in this country annually, and that the cost to the refiner for every ton of sugar refined was not less than 20s. per ton for the charcoal employed in the refining. Any process, therefore, which would effect a saving in the process of refining would relieve the public of a very heavy tax on the refined sugar consumed.

The defecating and decolourising power of pure animal charcoal was due to galvanic action; the charcoal was the positive electrode, or pole; the sugar and albumen neutral mediums, or inert agents of communication; and the colour and caramel the negative electrodes. It followed from this that the electrolytes were colour and caramel, and that these would be found attached to the charcoal, the inert medium, sugar and albumen, passing through the charcoal bed together. Again, as pure animal charcoal failed to separate albumen from a sugar solution, heat must be employed to coagulate the albumen, and then filtration to separate it from pure sugar solution.

In the production and refining of sugar, a temperature of 180° should never be exceeded. In treating cane-juice in the cold with pure animal charcoal, the sugar manufacturer should defecate and decolourise the solution in five minutes. The density of cane-juice was admirably adapted to this treatment; and the after process to free the purified juice of albumen should be as rapidly performed as possible. The juice would then be safe, as pure sugar in water would not ferment, or undergo any change, except that of crystallization. He had a specimen of a weak solution that had been kept for seven years, and no change had taken place in it except the formation of a few minute crystals.

The mere burning of bones would not produce pure animal char-

coal, however experienced the burner might be; for there was always animal matter left in them—sometimes of an offensive character—and always colour, which frequently injured the refiner's work. He could not too much impress upon those who produced and refined sugar the importance of having pure animal charcoal as a means of defecating and decolouring sugar solutions—and even molasses and treacle—in a few minutes.

Mr. C. W. SIEMENS said the Paper dealt with two separate subjects, one of a mechanical, and the other of a chemical character. It appeared to him that the Author had very satisfactorily solved the mechanical questions involved. The arrangements of the mill-gearing had evidently proved successful, but it was a question open to discussion whether so large a diameter of roller was beneficial in a chemical and economical point of view. By using large rollers a greater amount of saccharine matter could, however, undoubtedly be extracted. The system of raising the juice from one receiver to another by a centrifugal pump, instead of by the old 'blowing-up' arrangement, was also an improvement; because in admitting steam in contact with the saccharine solution, condensation would take place, and the work of evaporation would be increased; and if the centrifugal system was properly arranged, there need be no apprehension that it would churn the saccharine solution. Considerable ingenuity had been displayed in the construction of the evaporating apparatus employed. The steam boiler had been placed immediately below the concentrator, or, as it was called, the 'juice boiler,' and thus the steam generated in the lower compartment at once condensed against the upper surface of the steam boiler, which was also the bottom surface of the juice chamber—the surface contact being increased by means of tubes—and in that way losses of heat by radiation or otherwise were avoided, and the same water was re-evaporated again and again. It was interesting to observe that the surface in contact with the fire could be made three or four times smaller than the surface necessary to convey the heat from the steam to the saccharine solution.

The use of the steam raised from the saccharine solution was another novelty. It was made serviceable not only for working the vacuum pan, but also for driving the engine. There could be no reasonable doubt about the mechanical efficiency of applying the steam raised from the juice to driving the engine, and theory in this case had been justified by the result; but a question of a chemical nature arose, namely, whether the juice itself was not injured by raising from it steam of sufficient

pressure for such purposes. It was well known that when juice was concentrated by the direct application of fire, a considerable portion of the sugar was converted into molasses, or uncrystallizable sugar, and it would be desirable that the opinion of persons practically engaged in sugar boiling operations should be ascertained as to whether the direct application of heat had not been carried too far, or whether the same amount of juice would not have yielded a larger amount of crystallizable sugar, if the direct application of heat in the vacuum pans had been resorted to exclusively.

It might be urged that such an amount of heat could not have been obtained, owing to the larger consumption of fuel which would have been requisite; but there was a process now in course of trial, partly suggested by himself, to evaporate entirely by vacuum pans, and at the same time to economise heat by forcing the steam generated at low pressure within the vacuum pan mechanically into the tubes surrounded by the juice.

The main feature of the Paper was the substitution of sulphurous acid for charcoal in removing the colouring matter. If sulphurous acid could be applied without practical drawbacks, great saving must undoubtedly arise, because animal charcoal was an expensive substance, and involved the employment of complicated apparatus to revivify it for repeated use. But the question arose—whether in using the sulphurous acid method a portion of the crystallizable sugar was not converted into uncrystallizable, or grape sugar? It was a well-known fact that if sulphuric acid was put into a solution of cane sugar, its mere contagious action, so to speak, would convert an indefinite amount of the solution into uncrystallizable, or grape sugar, which, though very similar as to chemical constitution, was of a much less sweetening character. It was doubtful whether the sulphurous acid was always free from sulphuric acid, particularly if, as was suggested, oxydising agents, such as peroxide of manganese, were also employed. An increase of grape sugar would not necessarily imply a diminished yield, because when the solution came to a certain consistency it might solidify. He would inquire whether in the sugar prepared at the Aba mills there was not a proportion of uncrystallizable, or grape sugar precipitated with the crystallizable, or cane sugar? He did not believe in the theory put forward that galvanic action would be set up between the charcoal and the colouring matter. The conditions of sugar solution were totally at variance with what might be expected in a galvanic battery, where two conductors of different

affinity for oxygen were brought into metallic contact while immersed in acidulated water.

In regard to the experiments which he had referred to as having been conducted for effecting the concentration under a vacuum so as to attain the advantage of using the steam repeatedly, he might add that many years ago he proposed to evaporate liquid cane juice by pumping the steam from the vacuum pan, which was in the form of a locomotive boiler, into tubes surrounded by liquid in order that it might be condensed there. To sustain the further evaporation of the same liquid, a steam engine and pumping cylinder were employed, whereby the steam generated within the evaporating pan at about half the pressure of the atmosphere was compressed, and forced into the tubes at double, or atmosphere pressure. Its condensing point was raised in compression from 180° to 212°, which difference sufficed to cause the recondensation of the steam within the tubes and a continued ebullition of the juice, the same latent heat being made to serve over and over again. The only real expenditure in this operation was mechanical force, but the steam employed in generating this force was necessarily much less in amount than the steam compressed by it through half an atmosphere. Moreover, the exhaust steam of the engine was made available to make up for the loss by radiation, and for bringing the cold juice up to the boiling point.

Such a process could not fail to work practically, but the mechanism involved in it was of a nature to make its application costly. The project was revived last year by Mr. Robertson, who after hearing the Paper on "Pneumatic Despatch Tubes; the Circuit System," by Mr. Carl Siemens, M. Inst. C.E.,[1] conceived that the steam blast apparatus referred to, being capable of maintaining a vacuum of 20 inches of mercury, could be made to serve also to force the vapour raised in a vacuum pan into the evaporating tubes of the same or another pan, and thus to combine the advantage of evaporating the juice under a reduced pressure with that of repeatedly using the latent heat of the steam. Mr. C. W. Siemens considered this plan to be superior to that originally proposed by himself, inasmuch as the apparatus employed was simple and inexpensive. When tried in London, Mr. Robertson found that a vacuum of 20 inches could be maintained in his vacuum pan. In that case, as in the former, the steam employed in compressing the vapour in order to fit it for

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxiii., p. 1.

recondensation was added to the compressed steam and served to make up for losses by radiation, &c. It was evident that by such an arrangement the latent heat of the same steam could be used, not once or twice, but several times, the heat passing again and again through the same metallic surfaces. Whether such a plan could be worked advantageously in practice in the East and West India sugar factories was a question upon which Mr. C. W. Siemens had no experience to adduce, but the experiments had at any rate proved the correctness of the principle involved.

Mr. E. BEANES said he also thought that the diameter of the rollers for the mill were unnecessarily large. If the length of the rollers had been extended to 8 ft., three mills might have been made to do the work which four mills did now. He had seen rollers, 8 ft. long, work very well in the West Indies.

He had found no difficulty in the use of pinion or crown wheels when the rollers were set at a proper distance. An inch between the front roller and the top one was an unusually wide space. He had never seen more than $\frac{3}{8}$ths of an inch allowed. By the arrangement adopted by the Author, the whole of the work was thrown on the top and back rollers; consequently the gain in other respects in large diameter would be lost by the work coming on two rollers instead of three. He was under the impression that the large diameter had been adopted for the sake of feeding the mills better; but he had seen rollers of 28 in. diameter, with which there was not the slightest difficulty in feeding the mill. That might have been from the way in which they were turned, the last cut having been in the form of a fine thread graven with a pointed tool. He had seen those rollers fed by tipping cart-loads of canes from the railway directly on to the carrier.

There could not be much reliance placed upon statements of the percentage of juice obtained, because it depended upon the quality of the cane. He had seen 70 per cent. or 72 per cent. of juice from Otaheite cane, while with the same mill not more than 50 per cent. was obtained from ribbon cane.

So far as he had seen, no pump was so good as the 'montejus.' He did not observe any arrangement had been described for washing out the pipes and pump. That might not be so necessary in Egypt, because rich juice contained less nitrogenous matter than poor juice.

With respect to clarification by means of sulphurous acid, he would like to hear from the Author the part of the process which he considered to be new. If it was in passing sulphurous acid into cane-juice, and afterwards adding lime, that was the process of

Mr. Stewart of Louisiana, who had stated that he had established it in more than a thousand instances. If the Author first added the lime and afterwards the sulphurous acid, then it was a process copied from Mr. Beanes. It had been carried out on thirty-two plantations in Cuba, and also in Java, and it was about to be introduced into Queensland.

The bleaching power of sulphurous acid, as applied to cane-juice, was, he believed, one of its least valuable properties. If its colourless salts could be washed out, as was done when used for bleaching wool, it would be of some value even for removing a little colour; but this could not be done with cane-juice; and if the acid was neutralized, or evaporated from the juice, the colour would return. Its great value lay in what he had before stated, namely, its property of rendering insoluble the nitrogenous substance, gluten, not albumen or casein, as had been stated. The former was rendered insoluble by simply boiling the juice, the latter would be precipitated, when lime was added to it, by the formation of the earthy salt, calcium acetate. But such was not the case with gluten; it was not precipitated by either of those means.

There were some facts not generally known with respect to the decolourising power of animal charcoal. It was in proportion to the carbon—or call it carburetted hydrogen—surface exposed; and its power of absorbing lime was in the same proportion. He thought, if this were generally understood, such samples of animal charcoal as those on the table, being the kind used in Egypt, would not be exhibited. He had seen similar samples in some beet-root factories in the north of France; flints might almost as well be used as charcoal of such a size. Sulphurous acid, he had no doubt, would compare favourably with such charcoal as that.

Many—even chemists—were under the impression that the internal portion of the charcoal comes into action in decolourising; but such was not the case, as could be shown in many ways. For instance, as in testing it by lime-water—after it had entirely lost the power of removing lime from lime-water—if broken up into smaller pieces, thereby exposing new carbon surfaces, its power of absorbing lime would again return; but if all its pores had been filled before breaking it into smaller pieces, that result would not have happened.

The Author mentioned that the juice took up thirty volumes of sulphurous acid gas. If the gas was passed into hot juice, it would be impossible it could take up so large an amount. If it was passed into juice at a temperature of 75°, that quantity might possibly be absorbed; but it would take at least 24 hours to do it. He however believed that no such quantity could be used or was necessary

with the good quality of juice the Author worked with. A description should also have been given in the Paper of the chemical action which the sulphurous acid had upon the cane-juice.

Cane-juice contained gluten in more or less quantity, according to the soil on which it was grown. Rich soils gave it in considerable abundance, poorer soils gave but little. From the stunted size of the canes, which were only about one inch in diameter, he should infer that the canes which the Author had to deal with were grown on very poor soil. If juice at 10° Beaumé, being 1,070 specific gravity, took up thirty volumes of sulphurous acid, it would increase the density 13°, making it equal to 1,083 specific gravity; and therefore he thought it unlikely that quantity was used. Gluten ordinarily gave sugar-masters much trouble. This substance was soluble in the juice of the cane, as also in alkaline solutions; consequently, if the sugar-master put in too little lime the gluten remained in solution, and if too much, the same result occurred. Gluten was insoluble in sulphurous acid and the sulphites, and, by rendering it insoluble, it could be easily removed with the scum; but a much less quantity was required than was generally used. Malt contained very much more gluten than cane-juice, and it was found that 1 per cent.—of the weight of the malt—of acid sulphite of sodium was sufficient to render insoluble all the gluten of the malt.

He was of opinion that precipitators might do very well for the cane-juice; but when it became sirup at 22° Beaumé, the minute insoluble substances held in suspension took a long time to subside. Instead of the short time mentioned in the Paper, it would probably require twenty-two hours to clear thoroughly at 22° Beaumé. It was a mistake to finish the clarification at 22° Beaumé, because at that density the sirup contained matters which became insoluble as the density increased up to 30° Beaumé; therefore, if the clarification was carried on up to 30° Beaumé, and the sugar passed through bag-filters, the whole of the insoluble matters would remain behind, and the sugar would be of better quality.

A long experience had convinced him that sulphurous acid could not compete with animal charcoal where white sugar was required. To obtain a perfectly white sugar, an equally white sirup must be used, because a portion of sirup was shut up in the plates of each crystal, and could not be washed out. If merely grocery sugar was required, there was no objection to sulphurous acid; but it was unsuitable when white sugar was wanted. The whitest sugar made with sulphurous acid was grey, compared with real white sugar; and it would be unsaleable in the London market. Sugar-

refiners would not pay the price for it, and ordinary consumers would prefer the yellow sugar.

The apparatus for boiling juice under pressure described by the Author was not new; it was eighteen years old, to Mr. Beanes' knowledge; but he never approved of it, and believed that very serious injury might be done by it. To boil sugar under a pressure of 6 lbs. would be equal to a temperature of 231°. If a solution of perfectly white refined sugar was placed on a bath of common salt (chloride of sodium) and left there for three hours, it became quite yellow; now the boiling temperature of common salt was 224°, which was considerably under the temperature used here.

He thought the vacuum-pan was not the best kind of evaporator; at any rate, where it was used a larger heating surface than that described in the Paper would be necessary, especially with steam at such a low temperature. The use of megass alone as fuel was not a new idea, as it had been carried out for at least twelve years. He could give the names of several plantations in Cuba where megass was used, to the total exclusion of wood and coal.

Mr. JAMES B. ALLIOTT said, in the machinery under consideration the rollers were remarkable for their large diameter. In the operation of crushing the sugar-cane, there were two matters to be attended to: one was to have sufficient pressure to extract the juice, and the other was to take care that the already crushed cane did not in its passage out of the mill soak up the juice already extracted. So far as the latter point was concerned, no doubt large rollers were an advantage, because the distance between the place where the juice was expressed and that where the cane was expelled was greater than in small rollers; but so far as the power needed to produce a certain intensity of pressure was concerned, that would be much greater with large than with small rollers. The usual system was to make the rollers of such a diameter only as was necessary to give the requisite rigidity, and that might be obtained, with rollers of the length mentioned, namely, 5 ft. 6 in., by giving them a diameter of only 28 in. or 30 in. instead of 40 in., as in the Aba mills. There was, however, a greater surface of cane under pressure at the same time in the Aba mills than in the cases of smaller rollers. Therefore, if the pressure per inch of cane were the same at Aba as in mills with smaller rollers, much more engine power would be needed; or, if the engine power were the same, much less pressure per inch of cane would be exerted by the Aba mills than by those having rollers of the usual diameter. As had already been remarked, the

knowledge of the percentage of juice extracted was not very material, because it varied so much according to the quality of the cane; but it was of great interest to know what percentage of juice was left in the megass. On estates in which he was interested in the West Indies, he observed, this year, that the percentage of juice left in the megass had been about 47 per cent. of the total weight of the fresh megass. An average sample of megass, weighing 10 ozs., when washed in water and carefully dried, weighed 5·27 ozs., or rather more than half the original megass. From the quality of the megass as described—namely, that its loss in weight was over 40 per cent. before it was used for fuel—he should not infer that the megass was more perfectly crushed in Egypt than in the West Indies; and therefore it might reasonably be presumed that as perfect crushing was obtained with rollers of comparatively small diameter as with the very large rollers employed in Egypt.

Another matter which needed discussion was that of the evaporation of the juice under pressure. For years past the object of most of the inventions which had been made for the manufacture of sugar had been to reduce the temperature at which sugar solutions had been evaporated. Any temperature over 140° was prejudicial to solutions of sugar, and the damage done varied directly as the time of exposure to heat and as the square of the difference between 140° and the temperature attained. The evaporation in the trays at Aba was conducted under a pressure of from 3 lbs. to 6 lbs., which corresponded to an increase of the temperature above the normal boiling point of the liquor in the open air of from 8° to 16°.

Thus, taking 213° as the normal boiling point of juice, gauging 10° Beaumé, the injury done by boiling it in the open air for, say 10 minutes, would be represented by 53·29, while it would suffer, by being boiled for the same length of time under a pressure of 3 lbs., an injury represented by 65·61, and this would be increased to 79·21, were the pressure on the juice raised to 6 lbs.

When comparing the trays in use at the Aba factory with the ordinary Jamaica train or 'Triple-Effet' apparatus, this greater intensity of damage was to a considerable extent neutralised by the short time during which the juice was exposed to pressure, since it only remained in the concentrating trays about eighteen minutes, while in the ordinary train of open pans it would be exposed to the pressure of the atmosphere sometimes for an hour and a half, or even longer; and in the 'Triple-Effet' apparatus, though boiling at a lower temperature than in the open air, it would be exposed

for two hours, or three hours, to such a temperature as the pans attained. It might be that the juice did not suffer so much in the evaporating-tray as in the ordinary open train; but he did not think, on that account, that it was the proper course to evaporate under pressure.

With respect to the readiest methods of concentration, if the Aba tray were an improvement upon the ordinary system, certainly the 'concretor,' though condemned in the Paper as one of the rudest machines used in sugar manufacture,[1] presented advantages over the Aba trays. In the Aba trays the juice had a temperature of from 8° to 16° above its normal boiling point, and was exposed to this temperature for eighteen minutes, and this gave a concentration from 10° Beaumé up to 21° Beaumé. In the concretor the juice was concentrated from 10° Beaumé—not merely up to 21° Beaumé, but up to 28° Beaumé or 30° Beaumé—in less than ten minutes, and at a temperature from 8° to 16° less than that it was exposed to at Aba; this was if the concretor was being used, as it generally was, for making concrete sugar. If it was employed as a means of concentrating for the vacuum pan, the juice would be raised from 10° Beaumé up to about 20° Beaumé in seven minutes or eight minutes, and exposed to a temperature never exceeding 214°; while it would be raised from 20° Beaumé, to 28° Beaumé, or 30° Beaumé, by exposure for about fifteen minutes in another portion of the apparatus where it would only be subject to a temperature of about 170°, a degree of heat not much higher than it would be exposed to in the vacuum pan itself.

If, as was generally supposed, the application of heat was prejudicial to sugar—and if the damage caused was in exact proportion to the time during which the sirup was exposed to heat—he thought it would be found that the Aba trays were not an improvement upon apparatuses already in existence for many years past.

With regard to the defecation of the sugar, there could be little doubt that sulphurous acid gas possessed very powerful bleaching properties, and that it would remove a very large portion of the colour present in the juice; but if the whole of the sulphurous acid was not removed, some change went on in sugar which had been exposed to it. Whether it was because the sulphurous acid was gradually oxidised and became sulphuric acid, and thus caused the evil, he left it to others to say; but many instances of such changes had been related to him by those who had observed them.

Mr. J. G. C. C. GODSMAN expressed a hope that, in an alimentary

[1] *Vide* ante, p. 39.

and sanitary point of view, and considering the large consumption of sugar by the lower and working classes, the question would be fully sifted whether the use of sulphurous acid in the preparation of sugar was prejudicial to health as compared with the other process of animal charcoal. In the poorer neighbourhoods, his attention had been called to the inferior character of the sugars ordinarily sold, and in some cases to the circumstance that the acid with which they appeared to be impregnated had sensibly affected the paper in which the sugar was wrapped.

Mr. W. KNAGGS said he had patented the evaporating tray, referred to in the Paper, in 1865-66, and likewise the entire system of clarification described; and he went to Egypt and worked it. The large diameter of the rollers had been several times referred to, and some speakers expressed their opinion that they did not crush the cane so well as smaller rollers would have done. All he could say was, they did not crush the cane properly, because, being very short, a great depth of cane was required to feed them continuously. It was necessary to set the rollers an inch apart, consequently, with a glut of cane the mill stopped; and if the mill was slacked the cane came away unground. Had the rollers been longer and of less diameter, so as to admit of a wider feed, they would have done better. No experiments were tried at Aba to determine the capabilities of the rollers. He was there when the mill started, and he, his son and his nephew were the parties in charge of the mill. With regard to the sulphurous acid process, the Author had left out an important item in reference to the clarification. Not a particle of the sugar was made without the use of permanganate of soda, and part of Mr. Knaggs' patent was for the use of sulphurous acid combined with permanganate of soda. The action of sulphurous acid was to coagulate the albuminous principles in cane-juice and to bleach the green colouring matter and throw it up in a state of scum. An experience of thirty years as a planter and manufacturer of sugar had convinced him that this was the best means of clarifying the cane-juice. With the use of sulphurous acid and lime only, the juice generally remained cloudy; but the application of a small quantity of permanganate of soda left the liquor perfectly bright and clear. He considered the centrifugal pump was far preferable to the 'montejus' or the ordinary juice pump for raising the cane-juice. The juice pump was never in the same capacity as the flow of juice from the mill, and air was consequently injected into the juice, promoting decomposition and fermentation; while the 'montejus' was always more or less in a state of acidity and dirt.

The clarifiers, he considered, should have been square to facilitate the operation of scumming, as it was necessary in this process to remove the scum as fast as it rose on the top of the clarifier, before the lime was put in to neutralize the acids for purposes of boiling. The clarifiers acted well for the evaporating trays, the only innovation upon his original arrangement being that nozzles projecting upwards had been substituted for transverse tubes. But there was one great fault in connection with the alteration: the steam pipes in connection with the safety valves rose through the scum and froth of the boiling cane-juice, and as they were heated to a high temperature by a pressure of 60 lbs. of steam internally, the sugar became charred on their surfaces, and formed a black coating, which darkened the juice. He had protested against this arrangement.

Without wishing to detract from the merits of the concretor as a great improvement on the old copper wall, he considered that heating a thin film of the juice in the open air did more harm to it than heating it in close vessels not exposed to the air. The system of boiling the juice under pressure was contrary to his wishes, and that was the only originality the Author of the Paper could claim. The Author proposed to work the vacuum pans by putting a back pressure on the trays, a process against which Mr. Knaggs had also protested, and proposed instead that the Author should make the vacuum pans with increased heating surface beneath, so that the steam might escape freely from the trays.

He would offer no other remarks except to put forward his claim as being the inventor of these different processes, and to state that he worked the entire process at Aba from beginning to end.

Mr. Anderson said, that although, in the first instance, Mr. Knaggs had brought this system of making sugar under his notice, he found afterwards that what Mr. Knaggs claimed to have invented had been invented before. The sulphurous acid process had been patented in 1838 and several times since. Permanganate of potash, the use of which Mr. Knaggs claimed as a novelty, was not used in the experiments made by Mr. Ogston in Egypt, and, under the best chemical advice, had been completely abandoned. The tray was Mr. Knaggs' invention, improved by the introduction of the nozzles.

Mr. G. H. Ogston stated his belief that no permanganate of soda was used during his experiment at Aba. He always disapproved of it, and understood that Mr. Knaggs had, in deference to that opinion, given instructions to discontinue the use entirely whilst the experiment was in progress.

He would shortly state his reasons for objecting to permanganate of soda being introduced into solutions of sugar, especially in the presence of sulphurous acid, and chemists would readily recognise their importance. Sulphurous acid was converted into sulphuric acid by oxydation, the latter acid being highly destructive of cane sugar when boiled with it; and as permanganate of soda was an oxydating substance of great power, it seemed, in the last degree, dangerous to bring these bodies together in boiling cane juice. He had never seen permanganate of soda used during the experiment, and had every reason to believe it was not used.

Mr. W. KNAGGS said he had a letter from Messrs. Easton and Anderson, in which it was stated, that Mr. Ogston had made experiments in clarifications, and decided that the permanganate of soda process was beneficial and could do no harm whatever.

Mr. W. E. RICH remarked, with respect to the large size of the cane mill rollers, that their diameter was determined by the Khedive himself when the factory was first talked of. It could be easily demonstrated that large rolls required exactly the same power to crush a given thickness of cane at a given surface speed as small ones—excepting only a slight excess for overcoming the increased journal friction in consequence of the greater weight; and that excess might be estimated 'pro ratâ' when other things were the same. He could say with confidence, that no more power was used in crushing a given amount of cane between rollers of large diameter than in those of small diameter; and in sugar factories of sufficient extent to require one or more powerful cane mills, large rolls were decidedly preferable to small ones.

Time was an important element in the efficient crushing of fibres, and the time during which a particle of cane was under compression in a mill varied directly as the diameter of the rolls. In a mill with rolls of 4 ft. diameter, with a surface speed of 18 ft. per minute, the cane was subject to pressure during twice the time it would be in a mill with rolls of 2 ft. diameter going at the same speed. A rate of 18 ft. per minute was the established speed for cane mills in the West Indies, and the Aba mills were designed to run at that speed, but, in point of fact, they were run at 27 ft. per minute and 30 ft. per minute, sometimes even at 36 ft. per minute, with equally good results in the extraction of juice. Large mills could be made more rigid and stronger than small ones, and as they presented wider jaws for the reception of cane, a thicker layer could be carried through, and therefore much more work could be done. At Aba, the stream of cane into a mill was generally from 15 in. thick to 18 in. thick, and sometimes it ran

over the top rolls. The engines which worked these mills were capable of developing power three times as great as the average power necessary for driving them. This amount of power was required to overcome the jams occasioned by excessive gluts of cane, and the way in which such jams were overcome proved the strength of the mills. When a mill became choked and stopped, the practice was to reverse the engine, and then start it again at full speed, and the jam was overcome without the slightest injury to any part of the mill; up to the present time not a single casualty to the gearing had occurred.

The system of gearing presented great advantages over the ordinary system. At first, it might be considered complicated; but a closer examination would show there was no ground for that apprehension. Every pair of wheels was always in true gear with two or three teeth in contact, the load per inch of the width of face was in no case excessive, and, what was more, although there were ten wheels instead of seven, as on the old system, the ten were of smaller and more convenient sizes for manufacture and transit, and in the aggregate weighed 2 tons less than if the mill was made on the old system. Some remarks were made as to the strength of the copper vacuum pans. They were 10 ft. diameter and $\frac{1}{4}$ in. thick, and were built as nearly as practicable in the spherical shape. He did not know of any means of ascertaining the collapsing pressure on thin spheres of copper, except by direct experiment; but it was fair to estimate that a sphere 10 ft. diameter and $\frac{1}{4}$ in. thick was at least twice as strong as a thin iron cylinder 10 ft. diameter, 10 ft. long, and $\frac{1}{4}$ in. thick. If that were so, the collapsing pressure on these pans was at least 84 lbs. per square inch, or six times the maximum working pressure.

Mr. JOHN C. WILSON said he also had a claim in regard to a portion of the sugar mill described in the Paper. He patented the wedge motion for elevating the lower rolls on the 2nd of December, 1861. The arrangement in this case was the same, except that his wedge was inclined in the other direction, the large end outwards, and the small end nearest the centre of the mill. The latter arrangement had an advantage in this respect, that the strain from the pressure was not thrown outwards as in the case of the Aba mill, but was thrown inwards upon the side frame of the mill, and added materially to the strength of it.

With regard to the machinery, the condensing engine was not now considered to be the best engine for driving sugar mills, but it was admitted that either the horizontal or vertical high

pressure engine was the best, and these were generally used by the largest manufacturers of sugar mill machinery. The high pressure engine was economical in this respect, that the exhaust steam was used for heating the clarifiers, and it was in itself simple and economical, and did not require so much attention as a condensing engine. He thought there was an objection in having so much gearing close to the mill. It was much more convenient to have the gearing at a little distance, as it allowed the mill to be more easily cleaned, and had other advantages. He thought there could be no serious objection to the employment of the usual three pinions for driving the rollers; they had been in use for many years, and no practical objection had been found in their working. The roller most out of gear was the feed roller, and that had little work to do, being admittedly, in this mill, 1 in. away from the top roller. The megass roller did most of the work and was most in gear. He thought the ordinary rectangular clarifier, with heating pipes in the bottom, and a scum trough running all round the top, was much better than the one adopted. The heating pipes in the rectangular clarifier were immersed in the juice, and there was, therefore, no loss of heat with them, whereas, this clarifier, on the French system, entailed a serious loss of heat by radiation from the bottom casing.

He was surprised that no mention had yet been made of the fact that the open fire process was absolutely beneficial in the ultimate crystallization of the sugar when not extended beyond a certain point. It made a firmer grain with less molasses. The ordinary system of open fire evaporation in iron pans firing with megass, and the waste flame passing through a multitubular boiler placed in the flue of the copper, which raised all the steam necessary for working the whole plant of the factory, was found practically to be a very economical arrangement. Although he had pointed out what he considered would be improvements in the design of the work, he had no wish to detract unduly from the merits of the Paper. On the contrary, he thought the Author deserved great credit for the boldness and originality of his design, which appeared to have been well worked out.

Sir JOHN ALLEYNE, Bart., remarked that the rollers of a sugar mill had to be set in the best way for expressing the juice from the cane as a continuous operation, and they required no other adjustment after being set to the proper gauge. It was very different from the case of a mill rolling iron plates of different thicknesses. He thought, looking at the machinery as a whole, the amount of gearing in the Aba mill was more than there was

occasion for. He was acquainted with the working of three sugar estates in Barbadoes. On one of these the juice was raised by centrifugal pumps, in consequence of which the weight of the sugar was less, and its price decreased. The juice should have been run straight from the mill, and then both it and the gutters would have been accessible at all times for cleaning. If air was sucked in by the pumps the juice must be at a low level, and the pumps should be stopped till more liquor was collected. But the pumping was a great evil, and he believed it was increased by the high velocity of the centrifugal pump. It had been stated that the 'montejus' condensed a large portion of the steam, but the resulting evil was not great, because the juice was practically heated, and less mischief was done in reducing the density of the juice than the pumping did by promoting acidity.

Defecation by the sulphurous acid process was a main question, as it was important to ascertain how defecation could be best carried on with least waste. Not long since, he went over many beet-root sugar factories in Holland, and there the defecation was effected by carbonic acid. There was a limekiln on the works, with a blowing engine like that for blowing air into a blast furnace, by which the carbonic acid was pumped from the limekiln through the juice. The juice was first treated with an excess of lime, and the effect of the carbonic acid was to convert the lime into carbonate of lime, which was deposited as mud. He wished to ask the chemical gentlemen present whether that was what really took place, and whether that process did not stop fermentation much more effectually and give a better defecation than the sulphurous acid process did?

Mr. BEANES, by permission of the President, asked Sir John Alleyne whether he had ever seen an instance where carbonic acid had been used with sugar cane juice? He was under the impression that sugar cane juice contained acetic acid, and as that was stronger than carbonic acid it would maintain the lime in solution.

Sir JOHN ALLEYNE did not know of any instance where it had been employed with cane juice, though carbonic acid was used in all the beet-root factories in Holland he had visited; but he thought sugar could not be extracted from beet-root juice if the ordinary battery of open 'taches' of the West Indies was used.

Dr. HENRY LETHEBY said it must have been in the minds of all present that this was not altogether a question of machinery, for it involved other principles than those pertaining to mechanics. It was evident, indeed, from the general scope of the discussion, that many important chemical principles were concerned in the

economic production of sugar, and that these must be kept in view from the first moment the sugar producing plant began to sprout, until its juice was brought into the condition of crystallized sugar. In point of fact, many of the points previously touched upon were, to a great extent, subsidiary to the main question.

With respect to the growth of the cane, it was well known that if the soil was a little overcharged with saline matter, it would be found in the juice, and would seriously interfere with the production of crystallizable sugar. So, also, during the maturation of the plant, the amount of light, the presence of too much moisture, and the degree of temperature to which it was subjected, would affect the quality of the cane juice, not merely in its percentage proportion of sugar, but also in its richness in those nitrogenous matters which interfered with the production of crystallizable sugar during the processes of defecation and evaporation.

Turning, however, to one of the principal subjects of discussion, namely, the action of the rollers and crushing machinery, it was a very important question, whether it was really desirable to get all the juice possible out of the sugar cane; for it was a well-known fact that the juice first squeezed out, coming as it did from the loose cellular tissues, was much richer in sugar and less charged with albumen and saline matter than that which flowed from the harder tissues.

In the olden time, there was less difficulty in crystallizing sugar, and larger products from a given volume of juice were obtained than now, when so much greater pressure was applied, and when the yield of juice was, perhaps, almost doubled. He did not know the yield of the Egyptian canes, but formerly, in the West Indies, when not more than 50 per cent. of juice was obtained, sugar was made at a profit. Now, on an average, from 75 per cent. to 80 per cent. of juice was obtained; but that juice was so charged with nitrogenous and saline matters coming from the harder tissues of the cane, that he doubted whether it did not interfere very considerably with the profitable working of the sugar afterwards, and it was a question whether there would not be an advantage in separating the two juices from each other; for, ordinarily, they had a little less than two parts of saline matter in one thousand, and the same proportion of nitrogenous matter in the juice which flowed from the soft tissues; but, by higher pressure, sometimes nearly double that quantity of these objectionable impurities was extracted. It was evidently, therefore, an important point for consideration, whether it would

not be profitable to separate the juice of the first pressure from that of the second, seeing that in the first case a much better sugar was obtained than in the second.

With regard to the action of sulphurous acid, an examination of the cane juice under a microscope directly it was expressed would show it to be full of minute granules like corpuscular germs. These were, perhaps, the immediate agents of fermentation, which, in a warm climate, took place almost immediately. As a prime consideration, therefore, those germs must be killed at once. One of the most important effects of using sulphurous acid was that it stopped their growth, for it had the effect of immediately arresting fermentation. But it did more. There was a kind of albuminous matter in cane juice, which, like common albumen, was coagulated by heat. There was also another nitrogenous substance of the nature of caseine or legumine, which, like the albumen of milk, was not easily coagulated by heat. It was, however, coagulated by sulphurous acid, and, therefore, when this acid was added to the juice, it not only destroyed the minute germs which were ready to set up fermentation, but it also coagulated the other forms of albumen, and so helped to bring these matters to the surface as a scum in the after treatment of the juice.

As regarded the use of carbonic acid, it might in some instances act beneficially—as in the case of beet-root juice—by displacing atmospheric air; but he had no experience of its use in clarifying cane juice, and he did not think it could be substituted for sulphurous acid, for it was the especial property of that acid to coagulate, and so aid in the removal of those nitrogenous matters which interfered seriously with the production of crystallizable sugar, and which tended to convert it into the degraded or interverted form, called molasses; and, so far, the sulphurous acid had an advantage over every other form of gas in attacking these objectionable albuminous products.

As to the system of evaporating sugar under pressure, which was in operation in the Aba works, every chemist who had given attention to the subject knew that when sugar, either diluted or concentrated, was subjected to a higher temperature than 165° or 170° it was changed, or, as it was termed, degraded from its crystallizable character into uncrystallizable. It was, therefore, manifestly wrong to subject cane juice, under any circumstances, to a temperature higher than was necessary for evaporation; and unless fuel was so dear that it was too expensive to get steam otherwise than by the utilization of that which came from the evaporating juice, it was a most mischievous proceeding—judged, as he judged it, from a

scientific point of view—to effect the first evaporation of sugar in the manner described in the Paper. The subsequent processes of the manufacture involved chemical principles which required to be looked at in detail; but he might say the presence of albuminous matters, the presence of saline matters, the presence of minute quantities of acids, or even of alkali, from a too liberal use of it, were the chief causes of the degradation of crystallizable sugar; and although the machinery might be perfect, and the appliances for evaporation admirable, yet if these important causes of mischief were not taken into consideration, it would not be possible to realise to anything like the fullest extent the profitable manufacture of sugar.

Mr. E. A. Cowper said he did not think the advantage of large rolls was quite appreciated. He approved of the plan of driving rolls by wheels of larger diameter than themselves. The rolls for gold at the British Mint were so driven, as well as the rolls at the Sydney Mint, for which he made the drawings. Much greater steadiness was thus obtained, and the side-strain on the bearings was considerably reduced. Of course one roll must in this case be driven from one end, and the other from the other end; in each case the large wheel was driven by a pinion. There was by this means great leverage over the rollers, and much less chance of breakage. He thought large diameter was an advantage in taking in a heavy feed. In the case of the Aba mills, he understood as much as 18 in. thickness of cane was sometimes passed through. It was therefore evident the rolls must be further apart than if a feed of only 4 in. or 5 in. was put through; but the regularity of the pressure on a large mass of cane was greater than when a small thin layer was put in, as very often spaces occurred between the canes in which juice was liable to escape. He could not but think large rollers were best; they cost more, but it was money well spent.

Another advantage was that the cane was under pressure for a greater length of time, the pressure commencing at a point further from the bite of the rolls, and the consequence was that the canes, when relieved, had not the same opportunity of soaking up the juice again, like a sponge, as the juice was kept a greater distance back from the extreme pressure of the rolls than was the case when the rolls were small. Therefore he thought the larger rolls had a better effect in extracting the juice; and they certainly gave more time for the juice to get away.

Then there was the question of the power required to reduce the cane. It was immaterial whether that operation was per-

formed gradually or more quickly, if the reduction were the same. The work done was precisely the same in either case. There was, however, more surface of cane pressing against the large rolls than the small; hence the pressure on the bearings was greater, and—supposing the bearings were in proportion to the size of the rolls—the friction was a little increased.

One point should never be lost sight of in comparing the results of the different processes of manufacturing sugar, and that was the relative amount of fuel consumed in evaporating the juice. In the case of a very weak mill, only expressing 60 per cent. of juice instead of 70 per cent., there would be much more fuel in the megass in the form of sugar to evaporate the 60 per cent. of juice than there would be in the megass from which 70 per cent. had been expressed; and this lesser quantity of fuel would have the greater quantity of juice to evaporate. Taking these proportions, in the one case there were 129 units of fuel, and in the other 100 units of fuel, to evaporate a given quantity of juice.

With regard to the pumps, he thought that as a steady stream of juice was to be sent to the upper part of the mill, the centrifugal pump, with properly formed arms, was the best, as there was no churning up of the juice, or sending up air mixed with it; there were no valves to pass, and the juice would go up in a solid column.

The system of blowing steam in, notwithstanding its extensive use, seemed to him a very crude one, inasmuch as a certain quantity of water was thereby added to the juice, which had to be evaporated out again; to say nothing as to the objection of adding any water to raw juice.

With regard to the exact neutralisation of the acetic, sulphurous, and other acids in the juice, he thought hardly sufficient stress had been laid on this branch of the subject. If neutralisation was not perfect, a certain quantity of lime was carried away in the juice. It was well known to chemists that water with sugar in it would take up lime more readily than water without. Therefore it was important to have no excess of lime, as it would deteriorate the sugar, and 'fir' up the apparatus. He was very glad to hear that the sulphurous acid plan had been so well carried out, and that the clarification of the juice seemed to take place so satisfactorily, as it was a very great point to save the necessity of using animal charcoal, which was very expensive. It was important in neutralising any liquid, to see that the whole body of liquor in the pan was well mixed, or it could not be done accurately. The China clay, or whiting, appeared to be a good way of weighting the flocculent matter in the juice and carrying down the impurities.

With regard to the trays—as suggested by Mr. Knaggs—and carried out by Mr. Anderson, with the improvement of the nozzles and the addition of a little pressure—it seemed that the temperature could not be seriously injurious to the sugar. It was well known that good sugar could be made with ordinary pans exposed to a naked fire. If proper precautions were taken, he did not think that a steam temperature of about 290°, applied to the under-side of the pans, the juice being at 222°, was likely to do any serious injury in eighteen minutes.

There was actual proof that less molasses were made, because there was less burning by the temperature due to 3 lbs. pressure with the weak juice, and afterwards by the temperature of the vacuum pans, than there was with other processes. If any objection was still made to the 3 lbs. pressure, he would refer to the indicator diagram from the low-pressure engines (Plate 5); which showed that the steam was taken from the trays or concentrators, and used in the engine at a vacuum of 15 inches of mercury, so that the pressure of the steam in the cylinder was half a vacuum; and there might be that amount of vacuum in the concentrators, if desired, in which case the whole of the evaporation would take place under partial, though not perfect, vacuum. It was possible to do that, because the engine worked with so low a pressure; thus the juice might be under a partial vacuum the whole time.

In 1804, Richard Trevithick suggested the use of the steam from the juice being concentrated to work the steam engines.

Mr. BRAMWELL said the Paper embraced not only the bare facts relating to the manufacture of sugar and to the machinery employed, but also a statement of the principles on which the construction of the apparatus was based, and of the results obtained. It would afford data useful as well for other manufactures as for the particular manufacture under consideration. The Author had referred to some interesting facts in relation to the heating of water and of juice, showing the power of conduction under different circumstances. The question of heating might be divided into two branches: first, heating up to the point of ebullition, and secondly, heating after that point was reached.

From the results stated, it appeared that there were transmitted through each foot of surface per hour per degree of temperature of difference between the heating side and the side heated 260 units of heat, but that as soon as ebullition took place the power of transmission was raised to as much as 606 units; it further appeared that, when in the concentrator the juice was being dealt with, there was similarly a great difference in the power of trans-

mission, namely, 219 units while the juice was being heated, and 521 units after ebullition had commenced.

Many years ago Mr. Bramwell was occupied about the combined vapour engine of Du Trembley, and, as that engine was a novel one, he had to make experiments to collect the requisite information. It might be in the recollection of the members who had heard the late Mr. J. W. Jameson's Paper "On the Performances of the Screw Steam Ship 'Sahel,' fitted with Du Trembley's Combined-Vapour Engine, and of the sister ship 'Oasis,' fitted with Steam-engines worked expansively, and provided with partial Surface Condensation,"[1] that in the combined vapour engines the condensation of the water steam of the first cylinder was effected by surrounding the condensing surfaces with ether, which, in condensing the water steam, became itself evaporated for use as an ether steam in a second cylinder. Mr. Bramwell's experiments had been directed to the determination of the amount of surface required for the condensation of the water steam and also for that of the ether steam, and in the course of these experiments it was found that great effect was produced by using ether as the surrounding medium for surface condensation: this great effect no doubt arose from the fact that the ether was itself evaporated while it condensed the steam. He was not able to lay before the meeting the exact results of those experiments, but they were entirely corroborative of those given in the Paper. Last April he had occasion to make experiments upon the rate of heating and evaporation that could be obtained under varying steam pressures in a jacketed copper pan that contained 100 gallons up to the working level, and had to the same level 25 square feet of heating surface. He tried first with steam at 5 lbs., then with 10 lbs., then with 15 lbs., and finally with 20 lbs. above atmosphere. With 5 lbs. pressure, from the temperature of 58°, at which the water was put in, up to 200°, the transmission of heat per 1° of difference of temperature between the steam used and the water that was being heated—the temperature of that water being taken every five minutes—was (in units) 161, 151, 176, and 160, the variations being no doubt due to some inaccuracy of observation; but from a temperature of 200° to 212° the rate of transmission went up to 327 units; while when ebullition commenced the rate of transmission increased at once to 427 units. With steam at 10 lbs. above atmosphere, the rate of transmission while heating up to the boiling point per 1° of difference of temperature and per superficial foot per hour was 186 units of

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 233.

heat, and, after ebullition commenced, was 435 units. With steam at 15 lbs. above atmospheric pressure, the transmission after ebullition commenced was 458 units: unhappily at this pressure there was a failure to record the transmission prior to ebullition. And lastly, with steam at 20 lbs. above atmosphere, the rate of transmission appeared to be 205 units before ebullition and 488 units after ebullition. Taking the average, he might say that from cold water up to about 200° the rate of transmission was 162 units, close upon the boiling point 327 units, and at and after the boiling point was attained 427 units. These figures were not so high as those given by the Paper before the meeting, but the pan he used had been erected for eight or nine years, and probably the surface of the copper on the steam side was incrusted with deposit. He believed if the material had been new the results would have shown other figures, and would have brought them up to the level of those in the Paper; but as it was, the rates of transmission recorded corroborated the fact of the enormous increase of conduction the instant evaporation began.

It had been suggested by Mr. Anderson that the greater rate of transmission was due to the increased circulation of the water when ebullition began; but Mr. Bramwell doubted if that could be so. Whether the water were stagnant or not, he thought there was abundant proof in the experiments themselves that the temperature of the film next the skin of the vessel must be practically that of the bulk of the water, the proof being that, taking the temperatures of that bulk as the basis for the calculation, such a very uniform rate of transmission per 1° of difference of observed temperature was obtained. Now, it seemed to him, this would not be the case if, owing to the water being comparatively stagnant, the film next the skin became much more highly heated than the bulk of the water, and was not, therefore, as competent to receive further accessions of heat as it would be if the water were in rapid motion. The consideration of these facts led him to believe that the cause of the more rapid transmission of heat after ebullition commenced could not be due to the comparative non-mobility of the water before that time. On these grounds, he did not think the theory of Mr. Anderson was the right one, although he was not prepared to substitute another for it.

Mr. W. KNAGGS, in explanation of his previous remarks as regards the rollers employed in the Aba mills, said, that he did not object to the large size of the rollers; on the contrary, he agreed that large rollers crushed cane better than small ones, but the insufficient pressing of the cane was the result of other mechanical im-

perfections connected with the mills, which were, in his opinion, susceptible of improvement. At the same time he thought the advantage derived from the use of such heavy rollers and complicated gearing—notwithstanding the increased quantity of juice expressed—would not compensate for the extra cost and power required to work them.

With regard to the permanganate of soda, twelve months ago Mr. Ogston expressed some doubt as to the system, on the ground that the permanganate of soda might act as an oxydizing agent, and convert the sulphurous acid into sulphuric acid. Accordingly, some canes were brought from Egypt, and a series of experiments were made at Erith, by clarifying the juice with sulphurous acid, lime, clay, and permanganate of soda. The result was highly successful; he had a letter from Messrs. Easton and Anderson, expressing satisfaction with it; and subsequently 20 tons of permanganate of soda were sent out to Egypt, at an expense to the Viceroy of £1,600. He was, therefore, greatly surprised to hear Mr. Ogston say he knew nothing about the use of permanganate of soda at Aba. His son, who had charge of the clarifying at that place, was present, and he could testify that in every case there was a small addition of that substance. When the canes were of good quality, no doubt perfect clarification could be effected with sulphurous acid and lime alone; but the cane in Egypt was so inferior last season, that good clarification could not be obtained without permanganate of soda. It was not likely to produce sulphuric acid, because the sulphurous acid was neutralized with lime before the permanganate was applied, and it could only therefore convert the sulphite of lime thus formed into sulphate of lime; but even if it had been added to the juice prior to the neutralization of the sulphurous acid, and did convert it into sulphuric acid, the latter would have been immediately neutralized by the soda set free, and sulphate of soda would have been formed. He did not, therefore, think there was any danger on that score. He maintained that the description given in the Paper did not represent the process as performed at Aba. He started the mill, and left three days before the crop was over, while his son remained to finish the work.

Mr. G. H. Ogston observed that the effect of animal charcoal upon cane juice had been sufficiently studied to admit of defining the limits within which it could be economically employed, and of proving that although it would remove colour from vegetable solutions more perfectly than any known substance, it would not remove the objectionable nitrogenous compounds in cane juice

which were precipitated by some other means. As far as he knew, it was the universal experience, that dilute solutions of cane sugar, before or after treatment with animal charcoal, required to stand but a very short time, even at the ordinary temperature of this climate, before chemical change set up. In the whitest samples exhibited of finished sugar there was absolutely no inverted or uncrystallizable sugar, because they had been steamed in the centrifugal machine, whilst the darker ones were simply washed with dilute sirup. In those that retained a tinge of colour, there might be, perhaps, 0·5 per cent. of uncrystallizable sugar attached mechanically to the crystals; the fact being that the uncrystallizable sugar remained in solution in the sirups, when they were concentrated to a point far beyond that ever reached in a sugar factory. It therefore passed through the centrifugal machines, and constituted, after the last boiling, molasses, a product which was usually sent to the distillery for conversion into spirit. Even when concentrated to the condition of treacle, the sirup still failed to deposit inverted sugar, so that there was no possibility of any remaining with the first white products. The samples upon the table contained, in fact, more than 99 per cent. of actual crystallizable sugar.

The action of sulphurous acid upon cane-juice was two-fold. First, it precipitated—in the form of flocculencies—gluten, colouring, mucilaginous and other kindred complex substances containing nitrogen, and thus was more effective than lime alone. Secondly, it arrested the change which the substances still left behind—including sugar itself—were so prone to undergo, in regard to colour. It was the uncrystallizable sugar which more easily became darkened by the effect of heat alone; and as by the sulphurous acid process the colour of the sirups, when they arrived at the vacuum pan, was much less than by the ordinary mode, it seemed one proof that not only was the original colour of the juice removed by its agency, but that the easily-coloured inverted sugar was not produced during the concentration in nearly such large quantity as when the ordinary mode of defecation was used. Reference had also been made to the quantity of sulphurous acid required to produce the desired effect. It was extremely small, but the minimum amount had not yet been accurately arrived at, because the arrangements for distributing the gas were not so perfect as they have since been made. This point had not hitherto received the attention it demanded. He believed that not more than $\frac{1}{10}$ lb. of sulphur per 500 gallons of fluid would now be required—in all probability

½ lb. sulphur to the first ton of sugar would be sufficient. A misunderstanding had taken place as to the Author's meaning when he referred to the power of cane juice to absorb 35 times its volume of sulphurous acid gas. It was of course meant to indicate the extreme ease with which the gas could be applied, owing to the readiness with which it was taken up, and that precautions were in reality necessary to prevent its too rapid absorption by the juice.

Cane juice was so delicate a material to deal with, that no doubt the same watchful care should be bestowed upon its treatment with sulphurous acid as was taken with lime or other defecation; and the means for its exact regulation were in the present arrangement at hand. This was not entirely the case last season; and he believed that had there been more perfect control in this respect, better results would have been obtained.

It had been remarked that the samples on the table were none of them really white sugar, although they appeared to be so, and that on comparing them with English loaf sugar, it would be at once seen that they had a greyness of tint. There would seem to have been a misunderstanding as to what the Author meant to convey. There was no idea, Mr. Ogston believed, and certainly it was not his opinion, that sugar, as white as best English loaf sugar, would ever be economically produced, at one operation, from cane juice; and, at present, he did not think that sulphurous acid would take the place of animal charcoal in the second or refining process; but what was contemplated by the advocates of the sulphurous acid mode of treatment, was to produce as good results in weight and colour from cane juice direct as could be obtained by the use of animal charcoal, but at a much less cost. This had been more than accomplished at Aba, its produce being compared with that of Bene Mazar, which, in the same locality and under similar conditions, was excellently worked on the French mode and with animal charcoal.

He concurred with the Author, in attributing the success at Aba to the mill having been arranged from the beginning, with reference to sulphurous acid treatment; and he looked for better results when some small improvements, suggested by the experience of last season, were made in the gas apparatus.

It appeared that great diversity of opinion existed upon several of the more important questions that had been raised. It had been said that the best results could not be obtained in evaporating vessels in which the thermometer rose above 150° or 160°; and, on the contrary, it had been stated that the best sugar was only pro-

duced on estates on which the first evaporations took place in open pans over the naked fire; and he believed that the different results obtained in different places, by nominally the same process, were sufficient to justify a great diversity of opinion. The truth was, the extremes of the two conditions mainly tending, in properly defecated juice, to degrade sugar during the concentration of its solutions, were almost equally to be avoided; they were long exposure and excessively high temperature. Within certain limits, one of these evils was as destructive as the other; but they could not be very well considered apart, because, so long as the sirup was not too dense to circulate freely, a point approaching a high temperature might be reached at which the minimum amount of harm would be done, owing to the rapid evaporation it produced in a skilfully constructed apparatus.

Of course, if the question was broadly put, "Is it desirable to expose cane juice to a high temperature?" the answer must be in the negative. If, on the other hand, it were asked, "Would the evaporation occupy a long time?" the answer in the negative must be quite as decided; but as, in the present condition of the manufacture, a loss, by the production of uncrystallizable sugar, must be sustained, the machine to be sought for was an evaporator that would do the least harm in either direction. In the tray which the Author had described, it seemed that this result had been more nearly arrived at, than in any form of evaporator with which he was acquainted. The evaporation was extremely rapid, each particle of sugar being exposed for not more than 15 minutes or 20 minutes, and the temperature could under no circumstances rise above the boiling point of the solution, regard being had to the slight pressure maintained.

In any apparatus in which a much higher temperature was employed, although the evaporation might be more rapid, the danger of destruction by burning was unduly increased by the violent ebullition which took place, giving rise to the formation of large bubbles, which might leave portions of the heated surface dry, although but for an instant of time. He arrived at this opinion from investigations made some years ago on the rapid concentration of another organic solution, when the change which took place was shown to be much greater than was due to the general temperature of the liquid. It seemed that in the case of moderately dense solutions there was a liability of some portions of the substance dissolved being exposed, when the boiling was very violent, to a temperature nearly approaching that of the surface with which it was in contact. In the case of the evaporating tray, this

temperature was limited to that due to the steam pressure in the lower part of the apparatus, and the boiling was not so violent as to create much risk from that cause.

The figures the Author had laid before the Meeting were the result of a number of observations recorded by five independent observers, and this showed the success that had attended the arrangements at the Aba factory. The process of sugar-making could not, however, be said to be in a satisfactory condition, whilst so great a loss—in the shape of degraded sugar—was admitted to be necessary. Practically, the whole of the sugar in the crystallizable form was found in the juice as expressed from the canes; and during the short time it was under treatment from 5 per cent. to 25 per cent. was degraded into uncrystallizable sugar. In scarcely any other manufacture would such a loss be submitted to, and he believed it would not be long before much more satisfactory yields were obtained. Meanwhile, he thought that the arrangements at Aba were an important advance in the interests of sugar manufacturers, and that eventually their advantages would be recognised.

He had already expressed his conviction that permanganate of soda was not used during the time his experiments were in progress. He, however, knew that it had occasionally been added to the cane juice before he went out to Egypt, and he attributed its discontinuance to his frequently expressed disapproval. His belief was, that it was not used during his observations. He was many times a day on the clarifier stage in the course of his experiments, and he never saw it once used, and, therefore, for a great proportion of the time, he knew it was not used. There were also four gentlemen engaged in making the observations, one or other of whom was on the stage night and day, and no report had been made to him of its use. He was, however, quite satisfied that Mr. Knaggs believed his son, who had charge of the clarification, did use it. Permanganate of potash was an oxydizing substance of the most active character, and, besides yielding oxygen most readily to sulphurous acid, converting it into sulphuric acid. It would add a soluble alkaline salt—manganate of soda—to the sirup, and it was agreed by sugar refiners that any salt of that character would destroy five times its own weight of crystallizable sugar. For those reasons, he was opposed to the use of permanganate of soda as a defecator, and, at the best, he considered its use extremely dangerous.

Mr. John Dixon said that he had been in Egypt and had seen the machinery described in the Paper, and could bear testimony

to its excellence; but he could not help thinking that the Khedive, in spending so large a sum in the construction of such works, was really expending the national resources without any prospect of an adequate return. Egypt was strictly a producing country. It always had been so, and in no period of its history had it ever been distinguished for its manufactures. Those who were acquainted with the Egyptians of the present time would support him in saying they were not adapted for the pursuit of mechanical or manufacturing operations. It was not reasonable to suppose that they could succeed in such an enterprise when competing with the inhabitants of Great Britain, France, or Germany, where the manufacture and refinement of sugar was carried out to the greatest perfection. Sugar refining would not be more successful in Egypt than it had been in the East Indies, where it proved an entire failure; and he ventured to predict that a similar fate would attend this enterprise.

Mr. H. Davy, through the Secretary, remarked, that during the discussion of the chemical view of the manufacture of sugar some points were raised on which it was desirable some additional information should be given. He would ask whether in the sulphurous acid process the acid precipitated the gluten and other nitrogenous bodies present in the juice after expression from the cane? or were the foreign bodies precipitated by the boiling as scum, and the sulphurous acid used merely as an antiseptic and bleaching agent?

Some question had arisen with regard to the solubility of sulphurous acid in water, or solution of juice; the fact was, that the amount varied with the temperature; water at 0° centigrade absorbed 69 volumes, at 10° centigrade 51 volumes, at 20° centigrade 36 volumes.

It had been stated that permanganate of potash improved the crystallization and colour of sugar. That chemical compound was a powerful oxydizing reagent, and was used in Condy's fluid as a disinfectant, so that its action would probably be just the reverse of that desired, and cause the formation of other products than sugar; and if any sulphurous acid were present in the solution, sulphuric acid would be formed which would destroy the sugar. Experimentally, it might be possible to obtain favourable results, provided all the sulphurous acid were eliminated previously to the use of the permanganate, for if the organic colouring matter were more easily oxydable than sugar, then it would be oxydized and destroyed.

The action of animal charcoal in purifying sugar might be easily

observed, but was difficult to understand. Some chemists stated that the nitrogen held by the charcoal was the cause of the purifying action; others that it was effected by galvanic action, and others by absorption; but possibly the presence of phosphate of lime was the immediate cause, as charcoal which contained that compound acted more efficiently than charcoal without it. In the manufacture of sugar from the beet-root, a large quantity of calcic hydrate was used, far more than was needed to neutralize the acid present in the juice. Why so much was used he did not know—the juice containing the lime was boiled, and the scum removed. The compound of lime and sugar was not so easily acted on by heat as sugar in its pure state. After the scum was removed, carbonic acid was passed through the solution; the lime was deposited as carbonate, leaving the sugar to be concentrated. The sugar derived from the beet-root and that from the cane had the same composition and, he believed, the same chemical constitution. He did not consider lime to be inimical to sugar. Generally, all acids destroyed sugar, bases did not; but that proposition must not be taken as absolutely true, as the more alkaline the base, the less action it had upon sugar—thus potash had less action than lime.

There were other methods of purifying sugar which were simple in principle; but he was unable to state whether they had been tried on a large scale. When baryta was added to cane juice a precipitate was formed, consisting of an insoluble compound of baryta and sugar. The impurities remained in the solution. If this precipitate was separated from the solution by filtration and washed and then suspended in water, a stream of carbonic acid passed into the water would precipitate the baryta as a carbonate and leave the sugar in solution. Another method was to add the subacetate of lead to the cane juice; this carried down all the impurities as a precipitate leaving sugar in solution; the addition of sulphurous acid caused excess of lead to be precipitated as sulphite; the lead was so completely removed that no trace of it could be found. It was stated by chemists that sugar prepared after the old method contained far more lead than was obtained in this way. He trusted that some information would be given to the Meeting, with regard to these two methods of preparing sugar, and if such there were, the difficulties of their being carried out on an extensive scale.

As regarded the mechanical arrangements, he considered that, unless under very exceptional conditions, a vacuum pan should not be converted into a boiler. Supposing the pressure of steam to be 3 lbs. on the square inch, the temperature would

(approximately) be raised to 91° Fahrenheit above boiling point at atmospheric pressure. The increase of temperature and the longer exposure to heat would of course increase the proportion of uncrystallizable sugar. It was well known that the more rapid the concentration and the lower the temperature the less amount of sugar would be decomposed.

Mr. D. HALPIN remarked that the extra gearing in the machinery was probably introduced to modify strains which really did not exist. As far as he was aware, the old arrangement of three wheels had been found to answer all purposes. He believed there was no strain on the pinions, and when the top roller was running the others were driven as friction rollers. The difference in the width between the rollers had no effect upon the strain on the pinions. The driving wheel was 2 ft. 6 in. from the centre of the pinion, and he thought that mode of construction should have been avoided. The principal reason why rolling mills broke down was because they were connected by a mass of loose and insufficient framing. If they were put upon one frame, and that sufficiently rigid, accidents of that nature would not occur. Rolling mills were also frequently unequally set up, or in a direction in which the rollers were not parallel, and, with careless feeding, accidents took place. He thought the seven-wheel gear was preferable to the gearing adopted in the Aba factory, involving ten wheels besides extra shafts.

An opinion had been expressed that the mill should be placed above the clarifiers and that pumping should be dispensed with. He considered the centrifugal pump was the best, but that the cane mill should be placed high up, and the juice collected by gravitation. The use of the 'montejus' was very troublesome, but that of the ordinary cane pump was worse.

With respect to clarification, there were two systems—one by fire and the other by steam. The former was very old, and was seldom now used. It could not, he conceived, be advantageously used, owing to the fact, that the heat could not be stopped at the right point. There were two subdivisions of steam clarification —one high pressure and the other low pressure. High pressure was used in two systems. The French system, with a mass of pipes swung on trunnions on one side of the clarifier, was very complicated and difficult to clean. In the other system, steam jackets were used as in the Aba factory. He could not see the use of high-pressure clarification; low pressure was, in his opinion, preferable, if the steam was taken directly out of the engine. As a rule, if the sirup ran full from the mill the scum

was cracked by the heat of the waste steam from the engine as soon as the clarifier was filled.

It had been stated that the juice was boiled in the clarifiers at the Aba factory; he could not see any advantage gained by that practice, because, as the juice was boiled, the dirt in the liquor would become less capable of separation. The old low-pressure clarifiers, where all the steam was obtained from the engine, were much preferable to the high-pressure system. In the evaporating arrangement in use at Aba there was only one advantage, and that a slight one, namely, the juice was practically kept at a constant temperature. There was no advantage derived from evaporating under pressure, and he thought that with the pans used there it would be troublesome to keep the work going on. If they ceased running from any cause, and if the sugar got jammed in at one end, the result would be serious. The economy of working engines with 3 lbs. to 6 lbs. of steam was very questionable. He had seen much better sugar than that exhibited made in the old way, evaporated under atmospheric pressure and at a moderately low temperature.

There were two points in connection with the centrifugal machines which, he thought, were open to objection. One was that the whole of the centrifugals were connected together and driven by one shaft, and put in motion by some kind of friction gearing. That system had been largely tried, but he thought it was surpassed by the direct driven centrifugals, which start easily with a load without causing belts—as they were apt to do—to slip or break. He thought, with centrifugals of 40 in. to 48 in. running 1,200 revolutions to 1,500 revolutions per minute, third sugars might be cured as fast as they were made without being obliged to store them in the 196,000 gallon tanks provided outside the mill for that purpose, and also to avoid the necessity of washing, and thus destroying the grain of the first sugars. He would only remark further, that he could not see in the arrangement of the mill what advantage there was in keeping all the firing inside, and he did not see why the boilers and evaporating pans could not be ranged at right angles to their present position so as to get the firing outside the mill, which he thought would be a decided advantage considering the nature of the fuel—megass—and the temperature in the building, which must be almost tropical.

Mr. ANDERSON, in reply upon the discussion, said the discussion which had arisen upon the Paper had in a great degree neutralized itself, as several of the questions put and remarks made about

different parts of the machinery had been answered by gentlemen quite as competent to deal with the subject as himself.

With respect to the percentage of juice expressed, and the important relation that existed between the amount of fuel necessary for making sugar and the quantity of juice obtained, Mr. Cowper had fully explained the matter; and an interesting illustration was given to Mr. Anderson last week by one of the Engineers of the Colonial Company, who mentioned the case of a factory making sugar for years without using any coal at all; but where, after having put up a more powerful mill and strengthened the engine, they found, to their great astonishment, that they were obliged to use coal, inasmuch as with their stronger machinery they squeezed out more juice, and, consequently, left less fuel in the megass.

It had been stated that it would have been better if larger tubular clarifiers, and low-pressure steam had been used. Plain spherical clarifiers had been preferred to tubular ones, on account of the facility of cleaning and thoroughly mixing the lime and gas. With regard to low-pressure steam, there was no objection to its use, except in respect of time, the great object being to get the clarifiers to boil as quickly as possible.

Much altercation had taken place as to whether permanganate of soda had been used or not. He would say, from his personal observation on the clarifying stage, that he had seen many clarifiers let down without permanganate of soda having been added; and Mr. Knaggs had told him he only thought it was necessary with exceptionally bad juice. Chemists were so much agreed as to the pernicious effects of the salt that its use had been interdicted for the future.

The concentrators had been objected to on account of the high temperature due to working under pressure. This objection was perfectly valid; and if coal were not a matter of very important consideration, he should prefer concentrating the juice 'in vacuo.'

A mathematical law had been laid down by Mr. Alliott for expressing the injury done to the juice by time and temperature, to the effect that, taking 140° as the starting point, any greater temperature injured the juice as the square of the increase of temperature, and as the time. Assuming the concretors to do at 214°, and in ten minutes, what the Aba tray performed at 230°, in eighteen minutes, it followed that the latter must injure the sirup over $2\frac{1}{2}$ times more than the former. But Mr. Alliott had not said how this measure was to be applied. Let it be supposed that the percentage of molasses was the best test of the condition of the

sirup, and then see how the formula worked in practice. The two Australian mills, referred to in the table,[1] both used concretors, the one in conjunction with a vacuum pan, the other with a Wetzel pan, both also using animal charcoal. Neither of them made white sugar, but they produced from 41 per cent. to 48 per cent. of molasses; whereas the Aba factory produced only 34 per cent. But it might be urged that the conditions of soil and climate were not the same, and that the comparison would not be fair on that account. Then let Aba be compared with Bene Mazar. The two factories were within 6 miles of each other, the canes and soil the same, and the management identical. In the latter mill the concentration was performed in triple-action concentrators 'in vacuo,' at a mean temperature of 170°, in 105 minutes; and therefore Aba should make $1\frac{1}{2}$ more molasses, whereas it only made $\frac{6}{10}$ths. He must, however, do Mr. Alliott the justice to say, that he had since informed him by letter that, though he had the greatest confidence in the formula he had propounded, he was not the author of it, and believed it was arrived at from vacuum-pan experiments, at a time anterior to the invention of the concretor. He therefore thought Mr. Alliott was a little venturesome in trying to impose the law on the Aba concentration, especially as he had Mr. Anderson's table of comparative production to test his formula by.

With regard to the statement made by Mr. Knaggs, that he was the author of the process, and designer of the factory, Mr. Anderson had already expressed his regret that, in curtailing the Paper for reading, the introductory paragraphs, in which Mr. Knaggs' name was mentioned, were omitted. It was a purely accidental omission, and he repeated what was stated in the Paper, namely, that the process of defecating cane-juice by means of sulphurous acid gas and other ingredients, combined with rapid concentration, was first introduced to his firm by Mr. Knaggs; but he thought the discussion had clearly shown that, with the exception of the cane-mill gearing, which Mr. Knaggs certainly did not invent, there was nothing new in any of the appliances, or in the use of sulphurous acid. The factory was designed while Mr. Knaggs was in Jamaica, and without any assistance from him; and when he came to England, in 1870, Messrs. Eastons and Anderson had already commenced shipping the machinery. It was quite true that Mr. Knaggs protested strongly against several of the arrangements made, but Mr. Anderson had disregarded most of his objections; and to his firmness in that respect he attributed, to some extent, the success of the factory.

[1] *Vide* ante, p. 64.

In conclusion, he must say he had not brought this Paper before the Institution as a collection of new inventions; he merely claimed to have combined apparatus more or less known in such a manner, as to make a process hitherto unsuccessful a complete success. Not one of the experienced gentlemen who had spoken had challenged the accuracy of the table of comparative yields of different systems, nor had superior results been brought forward. These, after all, were the tests, when combined with economy of first cost and of working, by which the process should be judged.

December 3, 1872.
T. HAWKSLEY, President,
in the Chair.

The following Candidates were balloted for and duly elected:—ROBERT EDWARD FORREST, WILLIAM HALL, JOHN SKARDON HEYMAN, ROBERT MORTON, and HENRY ROBERT WARING, as Members; SAMUEL ABBOTT, JOHN ADDY, Stud. Inst., C.E., JOHN AITON, JOHN ROMILLY ALLEN, CRAWFORD PETER BARLOW, B.A., Stud. Inst., C.E., WILLIAM ADAMSON BARRON, GEORGE JOHN BURKE, JOHN MONTRIOU CAMPION, Stud. Inst. C.E., WILLIAM HENRY CLEMMEY, WILLIAM GRIFFIN DAVIS, GEORGE FREDERICK DEACON, FRANCIS HENRY EVANS, RICHARD THOMAS HALL, EDWARD WESTLEY JACOB, AILSA JANSON, FREDERICK JOHN JOHNSTONE, WILLIAM BENJAMIN LEGGATT, EVAN LEIGH, ALFRED DAVID LEWIS, Major JOHN FREDERICK ADOLPHUS MCNAIR, late R.A., EDWARD JOHN THEODORE MANBY, THOMAS THOMAS MARKS, Captain JAMES LAW LUSHINGTON MORANT, R.E., Lieut. WILLIAM GUSTAVUS NICHOLSON, R.E., WELLESLEY INNES NOAD, Stud. Inst. C.E., FRANCIS WILLIAM OTTER, ALEXANDER PAYNE, WILLIAM PELHAM RICHARDSON, JAMES ROBERTSON, ALEXANDER MANSON RYMER-JONES, CHARLES EDWARD SHEPHEARD, RUPERT TURBERVILLE SMITH, ARTHUR SOUTHAM, THOMAS SAMUEL SPECK, JOHN ALFRED STOCKWELL, HENRY TIVY TOMKINS, FREDERICK ROBERT UPCOTT, GRIFFIN WILLIAM VICE, JAMES HENRY WALLER, Stud. Inst. C.E., EDWARD BENTINCK WILLIAMS, CORBET WOODALL, HENRY ROBERT WOOLBERT, as Associates.

It was announced that the Council, acting under the provisions of Sect. III. Cl. 7, of the Bye-Laws, had transferred JOHN HOWKINS, jun., and FRANCIS WILLIAM WEBB from the class of Associates to that of Members.

Also, that the following Candidates, having been duly recommended, had been admitted by the Council, under the provisions