Discussion.

The President. The PRESIDENT said the profession of civil engineering embraced a great variety of branches, and it was the desire of those who directed the business of the Institution that each branch should receive attention in the Papers that were read and discussed. Thus, the first Paper of the Session was on Graving Docks, and no fewer than four different kinds of such docks were described—a subject interesting to those who, like many of the members, carried out public works. The next Paper dealt with the Construction of Small Arms, a very important subject, interesting particularly perhaps to mechanical engineers, but generally to the country at large. The third Paper read was on Gas Power for Electric Lighting—a subject of interest to electrical engineers, gas engineers, and mechanicians. The Papers on Smelting Processes, now before the meeting, were of interest to all members, but especially to mining engineers, metallurgists, and to those who studied chemistry as a branch of their profession. In that way, already six or seven different branches of the profession had been represented, and the Session was not yet one-half over; so that it would be seen that the intention of the Council was being satisfactorily carried out. He was sure it would be the pleasure of members to thank the Authors of the Papers now under consideration for the good service they had rendered to the Institution in bringing forward the result of their experience in those important processes.

Mr. Bayliss. Mr. R. T. BAYLISS had heard the Papers with great interest, containing as they did a most able explanation of the modern practice of smelting silver and gold in the United States. He would suggest that the Author of the first Paper, in estimating the average saving of silver and gold at 92 per cent., was putting it a little lower than the average practice in the United States. As a matter of fact, smelters generally paid for 95 per cent. of the silver and full value for the gold contained in ore, and he hardly thought they would do so if they only succeeded in recovering about 92 per cent.

Mr. Rickard. Mr. THOMAS RICKARD observed that there had been a conspicuous omission in the Papers in respect of the collection of fumes. The fumes had been treated as if they were almost of no consequence. They were of course somewhat unimportant when dealing with

Mr. Rickard.

silver, gold, and copper; but when dealing with lead they were of the utmost importance. The fact was, in lead-smelting at the present day, something like 13 per cent. had been shown to be capable of collection by means of condensation in galleries, chimneys, or flues carried away from the head of the furnaces. There were cases where that was done, *e.g.*, at Pontgibaud, in France, where ores were taken past the smelting-works on the sea-board, brought more than 100 miles inland, part of the distance by cart, the fuel was carried in the same direction, and the lead was sent back in competition with smelters who were almost in the midst of the coal-fields. In dealing with the furnaces at Torreon, he thought too much had been devoted to the mechanical construction of the works and the water-jacket. It was customary nowadays to lay a good deal of stress upon the water-jacket, which was, however, merely a necessary evil. A furnace protected by means of water sacrificed a material part of its heat in order to save its lining. It was much better, where possible, to bring the materials into such a condition by previous treatment that the water-jacket could be dispensed with. Again, the tendency towards exaggerated quantities per day was an evil justifiable only by the exigencies of certain local conditions. For instance, the best smelting of fallow ores was perhaps that done in Sweden and Russia, particularly in the great Permian district, where, dealing with copper ore containing only about $2\frac{1}{2}$ per cent. to 4 per cent. of copper, the slag contained only about 0·25 per cent. He doubted whether anything of the sort had been approached in America. Then, again, there was a tendency to dispense with what was of equal importance with hearth-smelting, viz., the preparation by calcination. That had never been better carried than in the works at Argo, Denver, and at Pontgibaud in France. At the latter place the process was so efficiently carried out by stall- and furnace-roasting that an air-blast of only 4 inches of water sufficed, whereas in the case referred to by the Author, the pressure often exceeded 20 inches. With a high blast there was a corresponding loss of lead by volatilisation. The Americans were endeavouring to do for England, what England had long ago done for Germany and France in iron smelting; but it was certain that, as railway communication increased, and the price of labour decreased, so they would revert to the old methods. There was nothing so perfect in smelting in America as there was in Europe; and if the handicap placed upon English production by extravagant import duty were taken away Englishmen could still manage to hold their own. The display of constructions of

Mr. Rickard. the kind shown in the Papers would give no proper impression of the relative merits of smelting processes. It was known that the furnaces yielded, under favourable conditions, more than the assay value of the silver. He knew of cases where silver and lead were smelted in such a way that there was an excess of 3 to 4 per cent. of silver over the total assayed contents of the ore purchased; and in purchasing nowadays, it was in competition with sworn assayers, who did not allow a margin of anything like 4 per cent. or $\frac{1}{4}$ of $\frac{1}{10}$ per cent. on the silver, and that was about as safe an indication as could be given of the perfection of the work. This was done with labour at about 4*s*. per day, at a total cost of 36*s*. per ton. It seemed to him that the Author overstepped the mark in claiming any merit for a system of smelting which lost 25 per cent. of its metal. If that were to be the future of smelting, the sooner it was unlearnt the better. He did not desire to appear prejudiced in the matter. All these things depended greatly upon local circumstances, and it was rather unfair to criticise them on that account. They could be criticised only on general principles, particularly as the tendency with regard to smelting was to exaggerate mechanical arrangements at the expense of good smelting principles. With regard to lead colic, he had found that by using ordinary precautions at the refinery and at the desilverization, and in collecting the fumes, the men could be kept clear of colic by using a little sulphuric acid in the water they drank. It had been found at the Pontgibaud works, that, by the use of a ventilator of sufficient displacement to take the whole of the fumes through a spray of water, much more of the fumes could be collected than they could by the dry method with large extent of flues. Further, by giving the flues an appropriate inclination, the fumes were brought out by water into large reservoirs and were allowed to consolidate, and in that condition they were taken back to the furnaces and very conveniently handled. With regard to the water-jacket, the claims put forth for the water-jacketed furnace meant nothing. In the first place it might be simply a modified Castillian furnace, or it might be a modified Pilz furnace, or it might be, as it often was, a modified Rachette furnace. It was as applicable in the one case as in the other. Really the term "water-jacketed" was a misnomer, and should be avoided.

Mr. Louis. Mr. HENRY LOUIS was glad of the opportunity, not so much of criticising an established process, without which many of the valuable silver and gold ores of North America could not possibly have been worked, as of asking a few questions for infor-

mation. His experience of smelting precious metals dated a good many years back, and was confined simply to calcining and matting in reverberatory furnaces; and he had no personal knowledge of the process described by the Author. In the first place he wished to understand how the loss had been calculated? 92 to 95 per cent. seemed an enormous quantity of precious metal to extract, if calculated upon raw ore that had to be calcined. In calcining, say, the telluride ores of California, the losses even in gold were heavier than from 5 to 8 per cent., and in calcining silver ores, especially where zinc was present, they were often much higher. As far as he could understand from the diagrams, he could not see that any provision had been made to catch the gold and silver that would be lost in the calcination process only. As to the losses that would probably ensue in the smelting-furnace, he was not competent to speak; but, in reference to probable losses in the fume, he would ask whether the well-established method in iron-smelting, of closing the furnace top with a bell had ever been attempted, and, if so, with what result? He would also ask if any attempt had ever been made to apply the smelting process to the concentrates from gold mills? Seeing that gold mills generally produced concentrates consisting of iron and arsenical pyrites, which were often rich in gold, it would seem that the calcination of these pyrites, either with or without previous matting, would give an auriferous oxide of iron which would form the very flux wanted in smelting siliceous lead ores. He would be glad to know whether any work in that direction had been done; also whether the copper-jackets used in the Lake Superior district in smelting copper ores had ever been applied in the copper concentration process alluded to in the Papers. Mr. Louis.

Mr. WILLIAM SEMMONS observed that it was important to notice that in the large works conducted at Argo in Colorado, for smelting silver-copper ores, the water-jacketed furnace was not used, but the old style of reverberatory furnace was applied, and in that particular instance, modification in the arrangement of the bars had given marvellous results in economy. It had been shown by Mr. R. Pearce,[1] the manager of those works, that there had been derived from the old Swansea furnace more than twice the work obtained during the time that the reverberatory furnace had been used by him about 20 years ago. Mr. Semmons endorsed the statement made by a previous speaker that the water-jacketed Mr. Semmons.

[1] Transactions of the American Institute of Mining Engineers, vol. xviii. (1889), pp. 52–72.

Mr. Semmons. furnace was the result of efforts to get over a great evil. When it was first established in Arizona, the cost of fire-brick, which had been stated in the Paper to be 5*d*., was then 5*s*.; so that one could imagine the very great difficulty of constructing an ordinary reverberatory furnace. And not only was the cost of the brick so high, but the material had to be carted 800 miles to the nearest station. He would mention the difficulties under which some of these operations were conducted. In Mexico, the works referred to were at an altitude of 9,000 feet above the sea-level. At the large works at Denver, the heat was so intense during the summer that they were obliged to have large cakes of ice and play water on them, in order to cool and make the air bearable to the men. He thought if the water-jackets were of so great advantage over the ordinary old method of smelting, it would by this time have been adopted by some of the English smelters.

Mr. Cowper. Mr. E. A. Cowper was sure the Institution was much indebted to the Authors for the communication of Papers of so practical a character. The first Paper showed how, under certain circumstances, it was well worth while to ignore any value there might be in a small portion of zinc, antimony, bismuth, arsenic, &c., in the ores treated, in order to smelt as much lead, gold, and silver as possible with a given amount of expensive fuel and labour. The careful proportioning of the various ores in order to obtain a "burden" that would smelt well was most instructive. That was done to some extent in iron-smelting, but then there was generally a particular ore or ironstone in great preponderance, so that it was absolutely necessary to pay most attention to the proper smelting of such material with lime enough to make a clean slag. Sometimes a small quantity of aluminous ore was added to such rich ore as hæmatite, merely to keep the furnace open. He wished to notice two points; the first a small one, and the second of more importance. In taking samples of any loose dry material, it was not sufficient, in order to thoroughly mix it, to pass it through a sieve having a circular motion, as then small lots were only distributed in circles, and any one small rich lot, or different kind, would only make one circle in the midst of the mass; but if it were passed through one sieve moving in a straight line, a spot became a line at once; and then, if another sieve below the first moved in a straight line at right angles to the first, that line became a plane, so that every small lot of material was distributed over the whole surface. The second point that he wished to refer to, was the saving of "fume" from such furnaces as those described in the Papers, or from lead or from Scotch furnaces.

The plan resorted to in the works described, followed the common old-fashioned idea of a long flue from the furnaces to the stack, and sometimes combined with chambers. That was a mistake, even if the flue were very long (it was sometimes $\frac{3}{4}$ mile in length), for the draught through the flue kept by far the greater part of the fume in motion, and carried it out at the top of the stack; but if, on the contrary, there was but a slight draught and the fume and gases moved along very slowly, say, at one-twentieth the speed in an ordinary flue, the fume would deposit in large quantity. The plan might be carried out in various ways, but a convenient one adopted by him was shown in *Fig. 1.* A large number of parallel flues F F F were placed on each side of the main flue M, to the stack. Those flues were situated at an angle to the main flue, and each had a small opening into it, so that it should only take its fair share of the draught; then the outer ends of each set of parallel flues were connected to a gathering-flue G, which, being connected with the main flue

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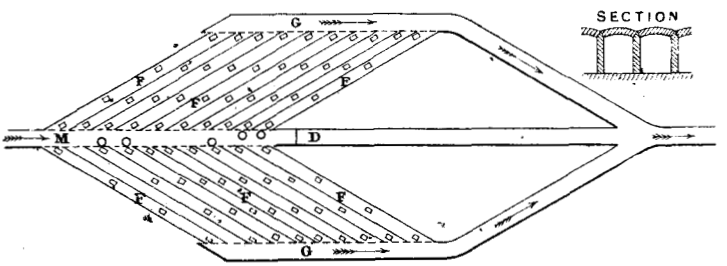
Fig. 1.



beyond the system, and a door D being shut in the main flue, obliged all the fume to be distributed equally through the parallel flues, and such products of combustion as were not deposited found their way by the gathering-flues G G to the main flue and the stack. This plan he had put before his friend, Mr. Sopwith, some years ago, and it had been at work most successfully in Spain since 1882. There had been an inspection of the works by an independent officer on the part of the Patent Office to report whether the plan was at work. From that gentleman's report it appeared that 190,000 lbs. of fume were deposited in 6 months, and that the arrangement was most effective. He had a further report of an extension of the plan to more furnaces, and in 8 weeks there was deposited on an average 3 feet depth of fume in the flues; and as the flues covered a good deal of ground, an

Mr. Cowper. enormous amount was thus obtained. The fume contained about 67 per cent. of lead. An incline had been arranged to convey this large quantity of fume more conveniently back to the furnaces for treatment. In the case of the gold and silver works, the fume would not only contain lead, but gold and silver.

Mr. Adams. Mr. THOMAS ADAMS enquired when the Papers were written. The information might be of interest as enabling the members to judge to what extent the Papers were up to date.

Mr. Hayter. Mr. HARRISON HAYTER, President, said that the Authors were abroad, but perhaps Mr. Collins, sen., could state when his son's Paper was written.

Mr. Collins. Mr. J. H. COLLINS replied that the Paper had only just been finished.

Prof. Roberts-Austen. Professor W. C. ROBERTS-AUSTEN considered it would be difficult for any Institution, even one entirely devoted to the interests of mining and metallurgy, to have two Papers better than those read, illustrating the recent practice on the American continent of smelting argentiferous lead. He was glad to say that both the Authors had been his students, but his interest in them was not merely professorial, though he might say that he was glad to find that young men from the School of Mines could go to the United States, where so much care was devoted to giving miners and metallurgists a thorough education, and could make good careers for themselves, and send home useful and trustworthy Papers. He could have wished that there had been some references to recent work and to Papers which had appeared in Austrian and German journals, and in the American *Engineering and Mining Journal*, reference, for instance, to the excellent book published last year by Mr. H. O. Hofman.[1] But it should be remembered that the Papers had been written, so to speak, on the field of battle, where there was no possibility of reference to modern works; and, knowing the literature of the subject, he could assure the members that the Papers were, in all respects, well up to date. He might observe that if the pan amalgamator was the typical appliance for operations in which the treatment of gold ores was conducted by amalgamation with mercury, the forms of water-jacketed furnace described by the Authors were the typical appliance in the modern lead smelting in the Western States. He had studied the works in the smelting district of Freiberg, and had seen the Grant Works at Denver, where many of the

[1] "The Metallurgy of Lead and the Desilverization of Base Bullion," New York, 1892.

operations described in the Papers were conducted very much as therein described; and there was certainly a great difference between the Continental and the American modes of procedure. It should be remembered that in these vat-shaped furnaces the ore and fuel were charged in pell-mell, but that very varied products found their way into the well, or crucible portion of the furnace at its base. The lead came down as metallic lead, and carried with it the precious metals and the bismuth; while copper came down mainly as sulphide, and the nickel and cobalt in combination with arsenic; iron found its way to the base of the furnace chiefly as slag. Those different materials arranged themselves by gravity, and could be separated. In the Freiberg district great care was taken to isolate the metals from the various products other than slag, and to bring all to account, even the small quantities of platinum which accompanied the precious metals. But in America, it was stated that the zinc was wasted, and that even speiss containing 12 ounces of silver to the ton was thrown away. He would be glad if the Authors would give some information as to those troublesome yet valuable associates of the precious metals, the tellurides, especially in relation to the loss of the precious metals which their treatment entailed. He wished to ask one or two questions about the slag. He was familiar with the slags which were treated at the Grant Works and with certain of the Mexican slags, and it appeared to him that those described by the Author of the first Paper were rather poorer in lime than was usual; but he supposed that the Author would agree to the American rule that slags should not contain more than 16 per cent. of lime, if as much as 10 per cent. of zinc was present in the furnace charge. The Author had stated that 8 per cent. of the slags were oxides of lead and of zinc. He should be glad to know what proportion he considered should be allotted to the zinc alone. There were two points that struck him, and would no doubt strike the metallurgical students present in the room, as of great interest. It had been stated that the whole of the precious metals could be collected in the lead, but in order to effect that collection, it was not necessary for the lead to exceed 10 or even 8 per cent. of the total furnace charge, and base bullion was then obtained which contained 400 ounces of silver to the ton. That seemed an extremely satisfactory performance. Copper had been employed with great success as an agent for collecting the precious metals, and when copper was so employed it was possible to use as little of it as 5 per cent. of the charge. That was interesting information, and he should like to hear

Prof. Roberts-Austen.

Prof. Roberts-Austen.

further details. No doubt 400 ounces of silver to the ton of lead would amount to some 80 ounces of lead for every ounce of silver collected; and that might seem large as compared with the 2 or 3 ounces of mercury to which was allotted the task of getting a single ounce of gold in ordinary amalgamation processes. But the conditions of working should be observed. There was a more or less pasty semi-fused mass; yet the lead had to go through that mass—had to find its way through the charge, take up the precious metal and carry it safely to the bottom. A new flux had been introduced—old tin cans, which were employed in considerable quantity in the furnace, not only with a view of affording sources of iron, but for the sake of keeping the charge open. The contents of those cans were well known to be extremely indigestible, and it was fortunate that a use had at last been found for them when empty. The value of the precious metal dealt with in the Papers was remarkable. The silver and gold, taken together, amounted to no less than £6,000,000. The gold value of the precious metals was about one-fifth of the total annual production of gold in the world, and about one-half of the amount of gold which the engineer and the metallurgist combined had converted into sovereigns during the past year at the English Mint; so that the amount of precious metal dealt with in the Paper, and representing the out-turn of about 9 works, was remarkable. One point that had struck him in reading the first Paper was the enormous advance that had been made in the engineering side of the question. Formerly metallurgy and chemistry were considered everything, and engineering was neglected. It was so when he assisted an old friend in smelting lead in Cornwall; but now all was changed. They had only to read the Paper and Mr. Hofman's book to see how efficiently the engineer had aided the metallurgist in recent metallurgical practice. With regard to the scale of charges and treatment, he wished to make one observation. In his evidence given before the Royal Commission on the production of gold and silver in 1887, he allotted 2*s.* as the cost of every ounce of silver obtained by the desilverization of lead. That figure was much disputed, especially by American authorities; but he was quite satisfied, after examining the scale of charges given in the Paper, that the 2*s.* would leave a very good profit for the extraction of an ounce of silver by the methods he had indicated. He wished to offer a word of gratitude to the President and Council of the Institution for admitting so many metallurgical Papers into its list. He thought he was right in saying that within the past two years there had

been no fewer than four metallurgical Papers read. Metallurgists were only too glad to have an opportunity of placing before engineers the difficulties they had, not only in extracting metals from their ores, but in adapting them for use. That usually involved either adding or abstracting a minute quantity of foreign matter, which would entirely change the mechanical properties of the metal, and render it serviceable. It was only by conferences like those that engineers could help metallurgists to overcome their difficulties, and that metallurgists could really appreciate the requirements of engineers. There were some other points he should have liked to raise as to details of the method of extracting the silver by zinc; but as the Authors were not present, he feared it would be of little use to ask those questions. Perhaps, however, Mr. J. H. Collins could state if it was found, in the desilverization, that the first zinc which came to the surface of the lead bath was specially rich in silver. Prof. Roberts Austen.

In reference to the concluding part of Mr. Rickard's observations, he remarked that American metallurgists had, in certain cases, adopted the reverberatory furnace when the precious metals had to be concentrated in copper, as was the case at the works directed by Mr. Pearce, at Denver. In American lead districts, the reverberatory furnace had not held its own, mainly because the ores were not, generally, sufficiently pure for treatment in the reverberatory; and where, as in the Mississippi Valley, the ores were suitable, the difficulty of obtaining skilled labour appeared to have been the main reason for not adopting the reverberatory in preference to the blast furnace. This reason may not have been justified, but the fact remained that blast furnaces were preferred. Doubtless, the adoption of a mixed system of reverberatory and blast-furnace treatment would be advantageous in certain cases.

Mr. W. W. WILLIAMS said he had just returned from Mexico, where he had had charge of the works described in the second Paper, which had been rather severely criticised in the first Paper. He would be able to prove that those works were carried on more economically than the El Paso works, which had been taken as a basis of comparison. He would first submit that it was hardly fair to make a comparison between works situated at El Paso (which, although it had a Spanish name, was in the United States), at the junction of four main lines of railway, where there were always plenty of men, with works at Las Trojes, in the centre of Mexico, a hundred miles away from any large town, where local labourers had to be put up with, and trained to Mr. Williams.

Mr. Williams. the work. Before making a comparison he wished to make three statements. Firstly, there was no ore so varying in its constituents as silver-lead ore. Iron and copper ores, especially when taken from the same districts, possessed great similarity; but in silver-lead ores, sulphides were as different from carbonates as the proverbial chalk from cheese. In the first Paper it was mentioned that at El Paso a carbonate ore was used containing 25 per cent. of lead, and large quantities of iron, to the extent of 50 per cent. Works using that could hardly be compared with works treating dry silicate ores, with a great deal of zinc and very little lead. Secondly, the Trojes ore differed very considerably from month to month. He had had men at one time working at one particular point in a mine, and bringing up ore which contained very little zinc and a great deal of iron; and from the same point, a month afterwards, it came out nearly all silica and zinc, and yet with the same quantity of silver in it. Thirdly, he would point out that the works had been, and still were, in a state of transition. A question had been asked as to when the Papers were written. The second Paper was written about 15 months ago, when the furnaces had just been put in place, but had not been worked very long. Two or three months after it was written, the Author of the first Paper wrote for information, and it was given to him, but he was warned that the works were entirely in a state of transition, and he must take the facts that were given with all reserve, because the proportions of mixture, &c., were being changed almost from month to month. That information was given about a year ago. In works extracting precious metals there were two divisions, showing themselves at once. The first was, whether they were using lead or copper as a base. There were few mines where they could use both, and choose which they would have. Then there was another division, not so apparent, but still more important, when making a comparison, viz., whether they smelted from their own mines, or whether they bought the ore and smelted it, practising what was called in the United States "customs" smelting. A "customs" smelter could please himself whether he would buy an ore or not; if he did not like it he need not have it. In smelting in conjunction with one's own mines, there was only a choice of two things,—either to smelt the ore, or to throw it away. If it contained too much silver to be dealt with in that way, it had to be either smelted or otherwise treated. He would ask how it was proposed to deal with an ore too rich in silver to throw away, containing perhaps 10 or 11 per cent. of zinc, and not more than 3 per cent. of lead. Perhaps the answer might

be that it should be crushed and concentrated, and the zinc then treated separately. Possibly that might do, but then other works would have to be erected. The zinc ore could not be thrown away, because the zinc carried silver quite as much as the lead. It was necessary to start expensive new works for treating one part of the material, or to smelt it. It had been stated in the first Paper that the total cost of smelting a ton of ore at El Paso was £1 9*s.* 9*d.*, and that at Las Trojes it was £1 10*s.* 8*d.*, a few pence more. At the same time it was mentioned that the price of coke at El Paso was £1 15*s.* a ton, and at Las Trojes £3 4*s.* 4*d.* He thought he had proved that, allowing for the price of coke, the work was being done cheaper at Las Trojes. Taking the figures given, and reducing them to the same denomination, it would be seen that at El Paso 646 lbs. of charge were smelted for 100 lbs. of fuel, and at Las Trojes 800 lbs. of charge for 100 lbs. of fuel. At the present moment Las Trojes was doing 1,000 lbs. of charge for 100 lbs. of fuel, which was a step in advance of any others that he had heard of. He was sorry that the Author had not accepted the invitation given to him to visit Las Trojes before writing the Paper, because he would have seen that they were not smelting their slag over and over again; but that they were using old slag, some inside the yard, and some from places 3 or 4 miles away, which only cost the carriage. It was slag, 50 or 60 years old, from ore which had been treated by the old Castillian furnaces; and all the silver had not been got out of it. He had seen such slag with 8 ounces of silver to the ton. Slag of that sort was very friable, and went easily through the furnace. He might mention a fact that seemed almost too strange to be believed, but was absolutely true. The charge had been arranged, and it had been settled that there should be so much litharge, so much lime, so much calcined and uncalcined ore; the matte from previous smeltings had to be put through, and a certain proportion of the slag also. If the slag was reduced no more charges were put through, and no less fuel was consumed. Five per cent. might be added to the slag, without increasing the amount of fuel; so that there was an advantage in putting an extra amount of the old slag through the furnace. At present slag containing $1\frac{1}{4}$ oz. of silver to the ton was turned out; not, as had been claimed for other works, $\frac{1}{4}$ oz. per ton; but if slag with 3 or 4 ozs. per ton were put in, and slag was produced with only $1\frac{1}{4}$ oz., it paid to smelt the slag. There were many ores containing 15 ozs. silver to the ton, which were less valuable than slag containing 5 ozs. to the ton, the latter being so much more easily smelted. With regard to

Mr. Williams.

Mr. Williams. matte, it was stated at page 147 that too much matte was made at Las Trojes. On page 160 it was stated that more matte should be made, but not put through the furnace. In his opinion matte was what a previous speaker had described water-jacket furnaces to be —a necessary evil, at any rate for the class of ore at Las Trojes. Matte was a product due to imperfect calcination. Shortly after he went to Las Trojes, he obtained permission to construct some roasting-stalls, by means of which the ore was calcined not only more quickly, but better; and the consequence was that the quantity of matte had decreased. It was mentioned in both Papers that the water-power there cost nothing; it was available at Las Trojes for ten and a-half months in the year, but still engines were needed for about 6 weeks at the end of the dry season. Another point raised was as to fuel. The charcoal at Las Trojes was cheap, but bad. The men had been accustomed to use charcoal, and, in fact, had no other fuel until about 3 years ago, when the railway was made. At the time when the second Paper was written, 7 parts of charcoal were used to 3 of coke. Two or three months afterwards, as would be seen by the first Paper, equal parts were used. Last autumn it was found that it was advantageous to further increase the coke and diminish the charcoal, and 3 parts of coke were used to 1 of charcoal, nearly reversing the proportions. That proportion could not be maintained, for, in such a locality, it was difficult to get regular supplies of fuel, and it had sometimes had to be varied according to what could be obtained. The San Luis Potosi Smelting Works used very hard coke, and no charcoal, but it was found at Trojes that with charcoal soft coke was better. Colorado coke was principally used. Mexican coke had been tried, but it did not give such good results. In the first Paper, it was said that the well became charged with lead in a few days. That might be the case at El Paso, but at Las Trojes the lead well was charged at the start, and it only held about twelve hours' supply. It was found that if the lead well was not charged, slag would issue through the siphon. He had the pleasure of seeing the works managed by Mr. H. F. Collins, and it was interesting to notice the ore converted direct into pig-copper. That certainly proved that he had got, what he described in the Paper as "a very docile ore, containing very considerable quantities of ferrous oxide and lime." A remark had been made about the use of old tin cans. He thought it was a very ingenious plan, but they were not used in the furnace. Old iron was largely used at Rio Tinto to precipitate copper in solutions in water. It had occurred to the Author that the

same plan would probably apply to copper when in a molten state, and he had introduced those tin cans with satisfactory results into a settler used before the slag was carried off. Even admitting the possibility of a comparison between the works described by the Authors of the two Papers, it should be remembered that in one case they were close to the United States, and in the other there was an additional 1,000 miles of haulage for the fuel, which would account for any difference if the works at Torreon were more economical. At the Grant and Omaha Smelting Works at Denver, there were 10 furnaces 33 inches by 100 inches in blast, and 8 more were under construction. There the matte was re-smelted; recently about 5 per cent. was being put back, and what they did nobody need be ashamed of doing. About 18 per cent. of lime was also used in the charge. Another large works was that of San Luis Potosi, where there were 10 furnaces 42 inches by 120 inches. All the smoke from these furnaces was conveyed under the yard and up a wooden stack 175 feet high. There was no smoke in the charging-floor, and simply a funnel or slit in the floor through which the charge was shovelled. He stood over it and there were no fumes at all. The length across the yard was not $\frac{3}{4}$ mile—perhaps not more than $\frac{1}{4}$ mile. The name of Mr. Pearce of Argo had been mentioned. Mr. Williams had had the pleasure of visiting the works conducted by that gentleman. They were very different from those which had been described and discussed. There were no blast-furnaces; and an interesting new furnace invented by Mr. Pearce was employed instead of the Brown O'Hara. It was called the "Turret" furnace. It had two arms, with cold air blown through them. Mr. Pearce considered that it was more economical, and that it required fewer repairs than the O'Hara furnace, which was driven by chains. It was stated in a pamphlet given to him by Mr. Pearce, that they were paying on about 80 per cent. of the gold ores. It had been stated by Mr. Bayliss, however, that at Montana they had paid all the gold and 95 per cent. of the silver, and he inferred that they saved 95 per cent. of the silver. He wished to learn the treating charges. It was better to pay on 95 per cent. of silver and charge $14 for smelting, than to pay on 100 per cent. and charge $16 for smelting—that was, it was better for the person who sold it. It was very easy for anybody to say: "You are working on a wrong process, and you should start something else." Companies had a considerable difficulty in deciding upon the right process to work, and it was very inconvenient and expensive to change a process. He had recently been in Virginia

Mr. Williams.

Mr. Williams. City talking to the foreman of the largest amalgamating works there, who had said: "We are all wrong here, we ought to smelt like you." Mr. Williams replied: "Wait till you have tried it; if there is anybody who ought to amalgamate and not to smelt, it is you."

Mr. Kitto. Mr. BENEDICT KITTO said he should be glad if some gentleman who had had practical experience in the modified form of the old English and Welsh furnaces as used in some of the larger smelting works in Colorado, would compare the results obtained therefrom with the results given in so much detail in the Paper. The water-jacketed furnace had been described by Professor Roberts-Austen as the typical furnace for silver ore smelting; but one would like to hear what could be said for the modification of the old English or Welsh smelting-furnace. The process of smelting which permitted speiss, containing 10 ounces and more of silver to be thrown away with the slag, could not be regarded as satisfactory. He agreed with Mr. Williams that it seemed hardly fair to compare the results obtained at El Paso, which was a customs smelting works supplied with different classes of ores, especially with those lead carbonates which were so useful in smelting, with works like that at Las Trojes, where only one class of ore had to be dealt with, and that refractory and difficult to treat. Some time ago he had submitted some of those Las Trojes ores to an inventor who had a new process for extracting silver from ores, and who, after assaying the ore, announced that he should concentrate the ore considerably. Mr. Kitto had replied that if he attempted to do so, he would lose a large portion of the silver. He had come to the conclusion, from examining the ore on a small scale, that it was impossible to concentrate the ore without a very heavy loss in silver; but the inventor in question had an original process of concentration, and was determined to try it. Mr. Kitto found in his tailings more than half as much silver as in his concentrates. The ore at Las Trojes contained a large amount of zinc, which was a troublesome thing to deal with in smelting silver ores. He had recently been experimenting upon a silver ore containing about 250 or 300 ounces of silver to the ton, and at the same time about 25 per cent. of zinc, with only 6 or 7 per cent. of lead. That ore was, he found, very difficult to treat so as to economically extract the silver. He thought they had got over one difficulty, that of roasting the ore without sustaining the heavy loss which usually occurred when ores containing such a high proportion of zinc were calcined. Still, the greater part of the zinc was left, and

the smelters did not like it. If a smelter, or any modification of existing smelters could be obtained, which could treat ores containing those large quantities of zinc, it would be most useful. Mr. Kitto.

Mr. Bennett H. Brough had listened with great interest and profit to the accounts given by the Authors of the marvellous development of the American metallurgical industry. At the same time he could not help being struck by the manner in which the labour-saving appliances in use throughout America were invariably accompanied by a disregard for the value of material. The same characteristic was noticeable in all branches of American metallurgical industry, and those who took part in the American excursion of the Iron and Steel Institute would remember that in the rolling mills in the Pittsburgh district, though most ingenious and elaborate devices for the automatic handling of ingots were seen, yet the amount of crop-ends that were produced was much larger than would be allowed in any works in Europe. Again, in the Connellsville coke region, there was not the slightest attempt made at collecting the by-products from coking. Similar examples could be cited from many other branches of industry. That state of things could not go on for ever; the time must come when more regard must be paid to the value of the raw material, and one could not help thinking that Americans would in time have to imitate the methods used in Europe in lead smelting, paying some attention to the recovery of the zinc, sulphur, bismuth and arsenic, which the Authors said were now entirely lost. In one of the Papers appeared some slight indication of the possibility of that tendency towards economy, in the statement that, at some of the works, the slag was used by the railway companies for ballast; but it seemed that the method employed was the clumsy one of running the slag from the furnace into trucks on tramways—a method which could not compare in any way with that adopted in the iron works of the Siegen district, where the slag, after granulation in water, was conveyed away by a wire ropeway and utilized for the manufacture of cement. A somewhat similar method had been seen by him at the Sudbury Nickel Works, but even there the slag was of no commercial value. On the other hand, on the continent of Europe, at the great copper works of the Mansfeld Company in Prussian Saxony, the slag industry had become of vast importance. There, slag from the copper works, after being de-vitrified by slow cooling, was used in the construction of paving-blocks, and last year more than 6,000,000 such blocks were made, showing to what an extent the utilization of Mr. Brough.

Mr. Brough. by-products might be carried. The Author of the first Paper had alluded to the narrow fissure veins of the Hartz mining district. Seeing that those veins attained the enormous thickness of 120 feet, that description could hardly be regarded as strictly accurate. In discussing the question of the dangers of lead colic, Mr. Rickard had mentioned a specific used in this country, where the lead smelters were dosed with sulphuric acid. On visiting the Mechernich lead works in Germany in 1891, Mr. Brough had found in use there a method equally efficacious and much pleasanter to the men. It consisted in compelling smelters before beginning work every morning to eat a piece of fat bacon; and that plan was found to answer remarkably well.

Mr. Terrell. Mr. WILLIAM TERRELL observed, with reference to the difficulties of blast-furnace treatment of ores that were rich in zinc and comparatively poor in lead, that in this country there was a method which would deal with those ores, if a reverberatory furnace were resorted to, viz., to mix such ores with oxide of iron if it could be obtained; and if not, to use old tin cans, first melting them in the reverberatory furnace to get rid of the zinc, after which they could easily be melted down in a blast-furnace, yielding bullion and good slag.

Dr. Ball. Dr. E. J. BALL was reminded by Mr. Terrell's remarks that the Freiberg slags contained up to 20 per cent. of oxide of zinc. The slags were very fluid, owing to the fact that the ores contained a considerable quantity of oxide of iron. Last year he had passed through Colorado to Idaho, and had visited a number of the smelting establishments *en route*. In regard to any criticism on the first Paper, it was difficult for those who had not visited the districts in question to fully understand the difficulties with which smelting was accompanied. As an illustration of the cost of living, and consequently of labour, in the case of one small smelter which he saw at Idaho, the smallest coin in use in the adjacent town, was a quarter of a dollar, and at Pueblo he was informed that half-a-dollar was the unit of value in everyday life. It was evident, therefore, that smelters could not treat at a profit such small quantities of speiss, containing a few ounces of silver, as those to which the Author had referred. Everything was done with a view of making profit with as small a quantity of labour as possible, and that particularly applied to smelting. Another point which, he thought, was rather passing out of view, was the consideration of the reasons for the failure of many of the smelters erected in the West. In the summer of 1890 or 1891 he visited British Columbia, and went to nearly all the smelting-

works erected there. A gentleman who had returned from that district only a few days ago had informed him that in the interval not one of those furnaces had been blown in. The reason for erecting them on modern lines was for the purpose of "booming" the adjacent real estate or mines, without any idea as to the cost of the material produced. A modern appliance had been mentioned which had been adopted for preventing the escape of fumes from the furnace. The appliance alluded to was in use at Freiberg a dozen years ago; it was not new. Many modern inventions or labour-saving appliances in the West were really older than had been supposed; still, he did not think it was fair to say that the smelting processes in England were better than those in the West, because the conditions were more favourable, and what would be best in the one case would not necessarily be so in the other. Dr. Ball.

Mr. T. K. Rose observed that Professor Roberts-Austen had remarked that tin cans were used for the double purpose of keeping the charge open and reducing the precious metals in the slag. A subsequent speaker had said their use was in reducing copper from the slag. Referring to the Paper, it would be seen that whatever the Author originally intended the tin cans for, he only admitted that he wished to keep the charge open and to reduce the precious metals. The slag preferred by the Author contained 46 per cent. of ferrous oxide; in which case much of the oxides originally present in the ore must have been reduced by carbonic oxide in the upper part of the furnace to metallic iron, consequently there must be a large percentage of metallic iron present when the tin can was added; therefore the use of the tin cans, if any, must necessarily have been to keep the charge open. He had been struck by the accuracy and fidelity of the descriptions of such of the smelting processes and furnaces of Western America as had been seen by the Author, particularly the descriptions of the lead-smelting process as carried on at Denver, Pueblo, and Leadville. There were one or two points, however, on which further explanation would have been satisfactory. He had observed in the Paper that one of the difficulties in smelting was the fineness of a large proportion of the ores offered. It might have been explained that this was due to two causes. One was that, in Denver at any rate, most of the ores in course of transfer from the miner to the smelter passed through the hands of public sampling-works, where the value of the ore was carefully ascertained. In order to do this, the whole was usually crushed by rolls so as to pass through a sieve of 2, 3, or 4 holes Mr. Rose.

Mr. Rose. to the square inch, thus making a good deal of fine ore. The other cause of the fineness of the ores was the large amount of sulphur in them, necessitating a preliminary roasting. To make this more effectual, the smelters crushed all sulphide ores not already finely divided. Thus at the Omaha and Grant Works at Denver, 150 to 200 tons of ore were reduced to the size of peas and even smaller by rock-breakers and rolls, as a preliminary to feeding it into the roasting-furnaces. He might add a few more figures which were supplied to him when on a visit to the Omaha and Grant Works in June, 1888. There were 440 tons of ore being smelted per day in the blast furnaces, one being set aside for fusion of matte. The consumption of fuel was 80 tons of coke and 15 tons of charcoal, besides 80 tons of coal in the roasting-furnaces, where 160 tons of ore and 60 tons of matte were roasted daily. The air to the blast-furnaces was supplied by blowers worked by a 250-HP. engine. At the time of his visit the yards contained ore of the value of $1,700,000. The charges for the blast furnace were made up on large mixing-floors. At the Grant Works, piles of ore were made from 6 to 10 feet deep and 100 feet or more in diameter, containing over 2,000 tons, composed of very thin evenly-distributed horizontal layers of different kinds of ore. When these piles were complete, vertical cuts were taken from them; and so the charges remained uniform for some time. Bullion was sampled by hollow punching, 2 cores being taken from each ingot. The cores from a carload of ingots were melted, and about four samples were taken. There was a slight ambiguity in one part of the Paper, where it was stated "gold is paid for at 95 per cent. of its full market value—about $18 per ounce." The mint value of gold in the United States was $20·67 per ounce fine; but smelters, he believed, always paid at the rate of $20 per ounce. In localities where miners would accept $18 per ounce as 95 per cent. of the value, smelters ought to prosper. The use of step-grates for roasting-furnaces at the Argo works, Denver, had resulted in great economy, as slack coal could be burnt satisfactorily. 1 ton of slack, he had been informed, was almost equal to 1 ton of large coal, and cost only $1·25 per ton, as against $4 for good flaming coal in large sized pieces.

Mr. Louis. Mr. D. A. Louis observed that among novel accessories in smelting-works, not mentioned in the Papers, was a centrifugal machine introduced at the Omaha and Grant works, at Omaha, for separating the globules of matte from molten slag; it was stated by its admirers to answer so well that, at the time of his visit in 1890

a similar plant had been shipped to Helena to treat the slags there. He thought it would be of interest if any information could be given as to the fate of that appliance. Its application, if successful, would result in the saving of much valuable metal, as well as the labour of picking over the slag by hand, referred to in the first Paper. The economy of treating slag or speiss containing a small quantity of silver, depended entirely on local conditions. He cited as an example of such apparently paradoxical economy, the fact that, in a small smelting-works in Montana, it was found expedient to smelt ore, even at the cost of some lead and other valuable constituents, because wood was scarce and coal dear. Fuel had to be economised, and the scheme was to let the sulphur replace it to a large extent. To this end, the silver and gold were concentrated in a copper matte in a hot-blast furnace; the blast being heated in a stove consisting of a vast rectangular chamber, through which the heated gases from the fire, at one end, circulated in one direction, whilst the blast traversed it, in 6-inch iron piping, in the opposite direction. The heavy arsenical fumes rolling out at the throat of the furnace, however, indicated the loss that was going on; nevertheless, the process was considered economical, and a larger smelting-works was being erected on the same principle in another district. In reference to the utilization of slag for cement, which had been mentioned in the discussion, it had not been so neglected as was supposed. The matter had been considered in the neighbourhood of a smelting-works where the slag was granulated, and where a suitable calcareous soil existed in the vicinity. A small grinding-mill was started, and a kiln, and large quantities of cement were made—for which, however, there was little or no demand. As to flue-dust, a striking contrast to the hot-blast copper-matting process alluded to, was furnished by the process in vogue at the Anaconda Works. The ore-bin at the Anaconda mills was constructed to contain 30,000 tons of ore. There calcination was conducted in Bruckner cylinders, and matting in reverberatories. There were ninty-six of these cylinders, each of 13 or 14 tons capacity, and the fumes, smoke, &c., ultimately passed into a long capacious flue of large section, built of masonry arched over with brick, following the slope of a hill terminating in the base of a high shaft on the summit. Considering the enormous amount of material used at the time of his visit, the amount of fume escaping was remarkably small; the weather, however, was then extremely cold.

Mr. Louis.

Mr. J. H. Collins said no one was more sorry than he at the

Mr. Collins.

Mr. Collins. absence of his son; but as he knew most of the works referred to, and was well acquainted with the processes carried on at Torreon, he would endeavour to reply to some of the points that had been raised. Particulars had been asked for, which were given in the Paper; and questions had been discussed as if they had not been referred to. For instance, Mr. Rickard said he found no mention of the important question of fumes and flue dust in the Paper. It might be that it did not treat the subject adequately; still, a considerable portion of the Paper dealt with that question. Again, it had been asked how the losses of the precious metals had been calculated. The particulars were given in the Paper. Many such questions would be found fully dealt with there. Then, again, many critical observations had been answered by subsequent speakers. Mr. Bayliss thought the Author had not done justice to the skill of the American smelters, when he said that they ordinarily utilized about 92 per cent. of the precious metal; he said it must be more than that, because they paid for more than that. A subsequent speaker objected on the very opposite ground, and said, so far as his experience went, not anything like 92 per cent. was recovered. Those remarks answered each other; and it might be that after all, the Author was not so very far wrong in his generalization. Some of the remarks made hardly seemed to be meant seriously, unless he had quite misunderstood them. Mr. Rickard had mentioned some smelting establishment where the output of silver was steadily and ordinarily 4 per cent. more than was shown by strictly accurate sampling and assaying. It reminded him of an examination question once put to him: "How would you detect hydrochloric acid in pure nitric acid?" All he could say with regard to an establishment where they got 4 per cent. more silver than accurate sampling and assaying showed there was in the ore, was, that he should not like to sell his ores at that place. Again, Mr. Rickard objected that there were too many details of construction in the Papers. He took it that any young man who went out to take charge of a smelting establishment or a mining establishment in an outlying district, away among the mountains, would not complain of Papers containing too many constructional details; and certainly those details would not be out of place in a Paper presented to the Institution of Civil Engineers. With reference to the question of clean slags, it was mainly, as had been said, one of local conditions. Where metal was cheaper than fuel and labour, there it was better to save fuel and labour; where fuel and labour were cheaper than the metal, there it was

better to save the costly metal. But it was not altogether a question of local conditions. Even in England attempts had been made to get copper slag too clean, even approaching the $\frac{1}{4}$ per cent. mentioned, and sacrificing three or four times the value of the copper saved in extra fuel. If that could be the case when coal could be got at 5*s.* or 6*s.* a ton, what would it be when coke had to be used at £3 a ton? With regard to the water-jacketed furnaces, it was the loss of heat which seemed to be the bugbear. The loss of heat in the water-jacket was not very much greater than in any other form of furnace. It was simply that the temperatures were much more localised. Any one going into a place where a large number of water-jacketed furnaces were at work would find that they did not radiate any large amount of heat; whereas on going into a place where there were furnaces of masonry, they would be found, after being at work for a short time, to radiate a large amount of heat. But this was not altogether a question of guess with the water-jacketed furnaces. With an ordinary masonry furnace, it would be difficult to ascertain what amount of heat was lost; but with the water-jacketed furnace, it was not at all difficult to come near the truth. In one of the furnaces described, the Author had stated that 7,600 lbs. of water were used per hour, and in the same furnace about 500 lbs. of coke were burnt per hour. The water, it might be taken, would be raised in that time about 55° Cent., *i.e.*, it would come out 55° Cent. hotter than it went into the jacket. He was speaking of a place where the water did not cool down very much before it was used over again. Working out these figures, it would be found that the total heat that went away in the water was between 9 and 10 per cent., and he much doubted whether, with an ordinary masonry furnace, the loss was less than that. One of the great advantages of these self-contained furnaces under the conditions in which they were used in America, was that they could be set up and used, though not of course to the best advantage, by men possessed of little metallurgical skill. They could even be used to smelt fine concentrates by using a low burden and a light blast. It was a mistake, of course, to suppose that the Author advocated the exclusive use of the water-jacketed furnaces; as he not only saw the necessity for reverberatory furnaces for some work, but would also acknowledge as soon as anybody that for some kinds of work they might advantageously use a blast-furnace constructed of masonry; still, for such conditions as he was dealing with up to the present time—transitory conditions, no doubt, to a great extent—the water-jacketed furnace

Mr. Collins

Mr. Collins. had proved itself to be the right thing. With regard to the tellurides, referred to by Professor Roberts-Austen, he thought there would be no difficulty in getting the gold out of them. It would not much matter whether the water-jacketed or any other furnace were used—if the tellurides of gold were put into it, the gold would be obtained in the metal or the matte. As for most of the questions put, he feared he must leave them unanswered, they would perhaps be answered in a subsequent Paper. With regard to the zinc found in the slags, it could not be very high. Generally speaking, the zinc would be volatilised. At El Paso the zinc and sulphur and several other ingredients, were lumped together, and were all included in the 8 per cent. He thought Mr. Williams should be obliged to the Author for giving him the opportunity of making such an excellent explanation. He did not know that he could say any more than that with regard to his complaint of the comparison which had been made, except perhaps this: Mr. Williams had asked what the Author would recommend to be done with an ore containing 10 per cent. or more of zinc and only 3 per cent. of lead? The Paper had stated his recommendation. His idea would be to make two operations of it instead of one; to smelt it first, after roasting as well as possible, so as to have the richest matte that could be obtained, to roast the matte again, and then add the litharge. Some remarks had been made by Mr. Kitto which were based on a misconception. He would find that the slags referred to did not contain 10 ozs., but less than 2 ozs. of silver, that the 10 ozs. material was the speiss, which was not produced in any large quantities, and so need hardly be discussed there. Mr. Collins certainly would have been glad to hear something more of a method of roasting a zinciferous silver ore without driving off any considerable proportion of silver, for it was no doubt difficult to roast an ore containing a large amount of zinc, which was also argentiferous, without losing a good deal of silver. Mr. Brough had defined the condition of American work generally and had also pointed out that it was a transition condition. Later on, as labour became cheaper and the costs of transport were lessened, the relative importance of the material would come in, and American methods would approximate to the methods of English smelters. He was also inclined to think sometimes that English smelters would find it well to let their methods approximate those described in the Papers; for if they had sometimes wasted material for the sake of saving labour, he was sure that in this country they had sometimes wasted labour for the sake of saving material.

Mr. Collins.

The Author's main position was very strong, although perhaps the title of the Paper was a little too wide. Instead of "Smelting Processes for the Extraction of Silver and Gold from their Ores," "Western," or "American Processes," or some such limitation, might have been used. But what he wished to bring forward was, that there were certain smelting processes for the extraction of gold and silver which were capable of large extension. The lead process, with its numerous advantages, was already pretty well known, and the Author hardly did more than describe and compare two typical works. The copper process was new, or nearly so. It was not generally applicable, but where it could be applied it was very valuable, since it admitted of so great a concentration as 30 or even 37 to 1 at one operation, and was moreover very cheap under favourable circumstances. The question of matte-smelting of concentrates and of pyritic ores was only lightly touched upon; but he agreed with the Author in thinking that, as roads and railways were extended, rendering the transport of fuel feasible, it would, following mechanical concentration in some instances, displace in many cases chlorination, the cyanide, Stetefeldt, and even the patio process, since it secured more of the valuable contents in a shorter time and at less cost. Further copper matte-smelting might even, in some cases, displace a lead-smelting process. An example of that came under his notice recently in connection with the Sunny Corner Works in New South Wales. There was a complex pyritic and zinciferous ore, which contained from 10 to 15 per cent. of lead and 1½ of copper. Neither the lead nor the copper were of any importance in themselves, but the ores contained always a good many ounces of silver and a certain small quantity of gold. For a long time, by a rather troublesome series of processes, involving more than one roasting, this mixed ore had been smelted on a lead basis. The lead produced was hard and impure, but of course it concentrated the silver and the gold. Within the last few years that process had been abandoned. The ore contained a good deal of zinc. It was found desirable to sacrifice both lead and zinc, to drive them away, to get rid of them as quickly as possible, and to work for a copper basis. Now the product was a copper matte of 30 to 40 per cent., in which the gold and silver were thoroughly concentrated. It was a much simpler process, and did not cost so much in labour. That was an example, and there would be others by-and-by, of lead-smelting being abandoned in the presence of a small quantity of copper for copper matte-smelting.

Mr. Collins.

Mr. H. F. Collins, in reply, remarked that several of the points

Mr. Collins. raised during the discussion were answered in the Paper. The 92 per cent. of gold and silver referred to by Messrs. Bayliss and Louis represented, as stated on p. 124, only the amount directly recovered as bullion and matte in the first instance. Of the remainder, a variable portion was always saved in the flue-dust; but, even if none were recovered, it would be possible for a smelter to pay for 95 per cent. of the assay-value by suitably increasing the "treatment-charges;" and this actually happened in some cases, not only in America but also in Europe. With regard to the smelting of concentrates referred to by Mr. H. Louis, the usual method was to calcine them in long reverberatory furnaces, and to fuse them down with siliceous ores in the fusion-hearth, so as to render their manipulation easier. No reference was made to the Argo works near Denver, nor to the Anaconda works in Montana, because both those works were on a matte basis; and the present Paper was already too long to allow detailed treatment of the matte-process. With regard to the old tin cans, their use in lead-furnaces was to keep the charge open and to aid in reducing the precious metals; while in pig-copper furnaces, their most important function was to assist the reduction of the copper. His only claim to originality consisted in the application of tin cans and similar scrap to the settler through which copper-slags passed before reaching the slag-pots. They acted by chemically precipitating part of the oxidized and combined copper in the slag, as explained by Mr. Williams, and their use for this purpose had proved to be a valuable innovation. In reply to Messrs. Rickard and Brough about waste of material, he endorsed the remarks of Mr. J. H. Collins on the subject. It was true that valuable by-products were often wasted in America, and that losses of material resulted from over-driving the plant; but in Europe expensive attempts were sometimes made to utilize by-products and to save material which it would be better financial policy to lose. Moreover, the output of European smelting-works was too often small in proportion to the amount of plant and the capital invested, through working at low pressure and handling the stuff too frequently. Some improvement had no doubt taken place in English works since his experience of 10 years ago; but he remembered that the arrangements in some of the principal works in Swansea, which he visited in 1883, left much to be desired as regards economizing labour and fuel; while the losses of copper and of lead were no lower than at the best conducted American works. In answer to Prof. Roberts-Austen, the Author had no experience with tellurides, but all the great Colorado smelters treated auriferous

ores and concentrates, whether containing tellurides or not, by calcination in the long reverberatory furnaces described, fusing down and running through blast-furnaces, and returned 90 to 95 per cent. of the assay-value of such concentrates. With regard to the same speaker's remarks about lime in slags, the Author would venture to state as his opinion that too much attention had been hitherto directed to the relative proportions of iron and lime in slags. The feeling seemed to be gaining ground among practical smelters, that, provided the ratio of silica to bases remained constant, the relative proportions of iron and lime might vary within tolerably wide limits without affecting the percentage of extraction. Thus the following slags, though very different in their proportions of iron and lime, would give substantially the same percentage of extraction in the furnace; and, though the latter would perhaps need a little more fuel and a somewhat slower rate of smelting, that often became more economical and convenient when iron flux ores were scarce:— Mr. Collins.

—	Slag, No. 1. $3(2FeO,SiO_2)$ $+2CaO,SiO_2$.	Slag, No. 2. $4(2FeO,SiO_2)$ $+3(2CaO,SiO_2.)$
	Per Cent.	Per Cent.
Silica	32	32
Ferrous oxide	45	36
Lime	15	24
Oxides of lead and zinc, aluminium	8	8
	100	100

Attention had been drawn to the ores of Las Trojes and to his criticisms on the smelting-process adopted for their treatment. Mr. Williams had stated that works for the extraction of precious metals by smelting processes fell naturally into two classes, according to the agent or base employed for collection. That was not quite correct, inasmuch as three distinct agents or bases might be used, as mentioned in the Paper: (1) metallic lead, (2) metallic copper, and (3) iron—or copper-matte; of which the two latter were as distinct as the sulphide from the carbonate quoted by Mr. Williams. Only the first two were described in the Paper, owing to lack of space, but the last was becoming increasingly important. Stress had rightly been laid by Mr. Williams on the fundamental difference between the ores treated at El Paso and at Las Trojes respectively; but that speaker had failed to grasp the inference that a process which was eminently suitable for one

Mr. Collins. class of ores and one set of conditions, might be altogether unsuitable for another class of ores and a totally different set of conditions. His criticism of the large amount of slag smelted had been based upon a misconception; but, as regarded his other strictures, he adhered to the view expressed in the Paper. The challenge thrown out to him, to say what ought to be done with ore like that of Las Trojes, had been anticipated on pp. 147 and 160 of the Paper, but the following details would explain more clearly his recommendations:

(1) Nothing but ore, slag and fuel should be run through the ore-furnace, except limestone-flux when necessary.

(2) The bulk of the ore should be stall- or kiln-roasted, as thoroughly as possible; and just enough raw ore should be added to produce matte in the proportion of 10 per cent. of the weight of ore charged. This iron-lead matte would average 150 ozs. per ton, and the slags would, if passed through a settler, be poorer than they were at present.

(3) The matte should be thoroughly roasted, preferably in a Brückner or other revolving-cylinder furnace; after which, while still hot, it should be charged into a reverberatory lead-furnace, with about one-fifth part of its weight of litharge, and small quantities of rich siliceous ores if obtainable.

(4) The lead-bullion, containing upwards of 700 ozs. of silver per ton, should be cupelled direct, the slags from the reverberatory furnace going back to the ore-furnace.

The necessary modifications of the plant for the adoption of this process would take some time, though the cost would not be great; once in steady working order, however, the saving in silver would be from 2 to 4 per cent. on the total amount treated, and the saving of lead would be much greater; there would also be a considerable saving in labour, on account of the larger quantities of ore put through the ore-furnaces and on account of the smaller amount of bullion to be refined. He believed it was tolerably safe to predict that, within the next 10 or 15 years, the matte-process above sketched out (with such modifications as might be rendered necessary by local conditions) would replace the ordinary lead-smelting process—not only at Las Trojes, but at all places where similar ores were met with in large quantities and had to be treated on the spot.

Mr. Malcolmson. Mr. J. W. MALCOLMSON, in reply to Mr. T. A. Rickard's remarks, to the effect that undue stress had been laid upon the utility of water-jackets, pointed out that the water-jacket was not an evil; no material part of the furnace-heat was lost, because the jacket

was always covered with a skin of slag which was practically a non-conductor. If it were possible to dispense with a water-jacket, it would be bad policy to do so. He had worked brick-furnaces, and considered the disadvantages of walls 3 feet thick, and the consequent difficulties of handling the furnace-charge, compared with the convenience and ease experienced in reaching the charge through a 6-inch cooled partition, alone afforded sufficient justification for the employment of water-jackets. Since the Paper was written, he had enjoyed opportunities of visiting most of the large smelting-works in Mexico, and had considerably modified his views with regard to the economical value of round furnaces; indeed, in the north of Mexico, the rectangular furnace was the only form used, and the tendency was to considerably enlarge its dimensions at the smelting-zone. With regard to the statements made as to the lowness of the grade of the base bullion produced at Las Trojes, he entirely agreed with the Author of the first Paper; but, at the time alluded to, the condensing-chambers and flues were not in operation, and an undue loss was feared on this account in enriching to any greater extent. In his opinion, too, the more extended application of matte as a vehicle for concentrating the silver and gold at Las Trojes, might be considered, especially as no important changes would be required in the existing plant. In a few districts of the United States, ores approximating closely in character and composition to those of Las Trojes, were treated satisfactorily in that way, with a consumption of less than one-fourth part of the fuel used at the Las Trojes smelting-works. The literature on this subject, however, was scanty, and any contribution respecting the details of actual operations would be much appreciated by metallurgists, especially by those who were working among the dry sulphide ores of Mexico. Mr. Malcolmson.

Correspondence.

Mr. D. W. Brunton stated that the smelting-furnace generally preferred in Colorado, was the sectional cast-iron water-jacketed furnace, 120 inches in length and between 34 inches to 42 inches wide at the tuyeres. Furnaces of larger size had been built; but while it was found that they would smelt without difficulty, there was no increase of economy in working, because the former furnace Mr. Brunton.