dent of the size of the tuyere opening, so long as the tuyere area available will permit of sufficient air passing into the furnace for smelting.

3. The pressure in the smelting zone is usually only 2oz. or 3oz., and should not be more than 5oz. or 6oz. below the pressure at the tuyere, as these differences of pressure are ample to pass into the furnace all the air required.

4. Variations in the pressure of the air in the blast main, cause almost equal variations in the pressure of the air in the smelting zone.

5. Variations in the size of the tuyere opening only vary the amount of energy required to force a given volume of air into the furnace, and do not materially vary the conditions of volume or pressure or smelting within the furnace.

Discussion

MR. SINCLAIR (in moving a vote of thanks to Mr. Tourney-Hinde for his paper) said:

Mr. Tourney-Hinde's paper appeals to me because it is just one of those papers which has a personal touch about it that we in this Association like to hear, as men who have actually measured things and done things themselves make interesting speakers. Personally, I am not on familiar ground in dealing with smelting furnaces and mining matters, and there are probably others here of the same way of thinking, and there are some things upon which I think Mr. Tourney-Hinde might give us a little more information.

I am not quite clear as to whether the air is heated before going into the furnaces or not, and if it is heated, to what temperature is it raised? Then, again, there is the question of the water jackets. I take it that these are put there for some purpose, and, as I confess I am not clear exactly on this, I shall be very glad to have this information. Then, as regards the temperature inside the furnace. Most of us know that if you put too much air into any ordinary furnace, all that happens is you blow it out; and I suppose there is some method of determining just how much air can be put into these blast furnaces, as I take it that the interior of the furnace is not always under observation, unless in the immediate vicinity of the tuyere openings.

I am interested in the point that Mr. Tourney-Hinde raised about pressure inside blast pipes. I remember once being inside a forced draught pressure main; certainly there was not more than 3in. of water pressure, but the curious thing that struck me about it was that I could move about inside the main trunk with an engineer's hand-lamp; but I had to cross an opening which took the air away, and the lamp was immediately blown out. I merely mention this to show how still the air apparently is in large pipes used for the purpose mentioned until it comes in front of small openings.

I have made some notes of remarks made by Mr. J. Caley, before the Iron and Steel Institute in New York. These notes I thought might have some bearing on this matter under discussion, more especially with regard to the condition of air supplied to blast furnaces generally. It was found in America that the humidity in the air made a great difference in the quantity of coke needed to be used in an iron and steel furnace. I presume in every other smelter, such as copper, lead, and so on, they would have humidity to contend with also. The method of working is this: atmospheric air containing the ordinary degree of humidity is passed over a set of cooling coils which reduces its temperature, consequently this means that the saturation point is reduced, and the excess moisture deposited on the refrigerating coils. The air is then led to the blowing engines, thence to the air heater. In operation, a plant, with ordinary atmospheric air, showed a production of 358 tons of iron with 2147 lbs. of coke per ton of iron, while with the dry air it showed 447 tons of iron with a consumption of 1726 lbs. of coke per ton of iron. Then, again, owing to the air being cooler, the amount taken in by the blowing engines was much increased; for instance, the H.P. for each blowing engine was 900 I.H.P., and after its use 671 I.H.P., or a difference of 229 I.H.P. per engine. These figures show an astonishing difference, and in the course of his paper Mr. Caley went on to give a log showing the temperature and humidity. Taking one example, the grains of water per cubic foot of air was reduced from 6.78 to 1.48 by reducing the temperature of the air from 73 to 23.

I have much pleasure in moving a vote of thanks to Mr. Tourney-Hinde for his paper.

Mr. William Poole said: I have very much pleasure in seconding the vote of thanks to Mr. Tourney-Hinde. This paper has been one of great interest to me, because for a period of three years I occupied the position of Night Superintendent at Port Pirie Smelting Works. In that capacity I had the responsible supervision of all branches, including the power house, of this large metallurgical plant.

It might be of interest to give you a brief resume of the early, and the present, practice, at those works. Originally most of the smelting was done at Broken Hill—that was in the time of the oxidised ores. The smelting of the carbonates presented no great difficulties in running the furnaces, but the metallurgical losses were exceedingly high. Later on, great difficulties were encountered in smelting the sulphides. The furnaces were shifted in every case away from Broken Hill to the seaboard, so as to be more conveniently situated to the sources of supply of fuel and fluxes. A very much larger quantity of fuel was required in the total operations. Large smelters were erected at Port Pirie. There was a series of thirteen furnaces; eleven were 212 inches long by 62 inches wide, the two smaller being 120 inches by 60 inches. The width of the furnaces I am particularly anxious to state, because I do not think (except one afterwards erected at Fremantle) such widths were ever attempted before, or since. Lead smelters usually claim that the blast penetration is not effective for such great widths. The furnaces at Port Pirie were originally provided with projecting water cooled tuyeres which projected nine inches on both sides; but if they cracked, the water was turned off, and they were allowed to burn out, as it was a bother to replace them until the furnace was closed down for repairs. At a later date the tuyeres were made flush with the inside of the water jackets, as at other lead smelting works. The blast penetration was found effective with the higher blast pressure that had by that time been introduced.

There is another interesting point there, viz., that originally there were several mill engines working on the large main shaft, from which a series of blowers, of the "Green" make, were operated, all of which at first delivered into one general bustle pipe, all the furnaces at first receiving their blast from this one pipe. As time went on, it was noticed that the free running furnaces practically robbed the slower furnaces of their supply of air. Every fast running furnace is more or less free or loose in the charge, and therefore allowed more than the average quantity of air to pass through, while the slow, tightly charged ones, which really required extra air, did not get it. To roughly indicate the quantity of blast to each furnace, little impact indicator discs were placed in the branch wind pipe to each furnace. Each indicator consisted of a small suspended disc operating a small pointer on the outside of the pipe. It did not give numerical values, but did give relative values, quite sufficient to the staff to show which furnaces were properly taking their wind, and which were not. If some were not receiving a sufficient air supply, the freer ones could be regulated down so as to give the others a greater supply. At later dates separate bustle pipes and blowers were provided for some at least of the furnaces. This illustrates the problem which was once very largely discussed amongst metallurgists, viz., whether it was preferable to maintain a constant blast pressure or to supply a constant quantity of air irrespective of pressure. It is now acknowledged amongst metallurgists that to obtain good furnace work it is necessary to provide each furnace with its own blower and main, so as to have an independent supply of air, which may be regulated to meet the needs of that furnace; quantity, not pressure of air, is the ruling factor. Tall furnaces require high blast pressures to maintain the necessary quantity of air. The tightness of the furnaces is produced by several means. One of the most serious detriments to free running furnaces is the presence of fine ore, coke or flux—in fact, fine material is often added to a furnace to slow it down—sometimes by instruction, but more often maliciously by the feeders to save themselves work in charging the furnace. The supply of air to a furnace is necessary not only to burn up coke, but also to burn off the remaining portion of the sulphur left in the charge. It is usual at lead smelteries to reduce by roasting the quantity of sulphur as much as is commercially possible before the ore is charged to the blast furnace. If sulphur is roasted and converted down to three per cent., especially if half the sulphur is in the form of sulphate, it is satisfactory to the metallurgist. After they started to treat sulphide ores, various methods were tried to avoid using concentrates in a fine form, not only on account of damping down the furnaces, but also on account of the large losses due to the fine materials which were blown out into the flue, causing flue-losses, a large quantity of which is drawn up into the shaft and permanently lost. One method used before the introduction of the Huntington and Heberlein sintering process was to mix the concentrates with a small proportion of lime —usually about three per cent. or four per cent.—and to briquette the material and, after drying, to feed the large lumps into the furnace.

During the period when I was first at Port Pirie, viz., in 1901, the average blast pressure ran from about 12 to 15 ozs., and it was gradually increased up to 30 or 35 ozs.

An interesting experiment was made with a Green blower to ascertain the maximum pressure of blast obtainable. The Green blower is a rotary impeller blower, and not a positive piston blower like the machines described by Mr. Tourney-Hinde. The outlet valve was closed, the maximum pressure obtained was 60 to 65 ozs. per sq. inch, and at this pressure the air slipped back past the impellers. There was no difficulty at the Port Pirie works in working up to from 30 to 35 ozs. of pressure. Since then there have been improvements; that particular type of blower has been discarded, and turbo-blowers have been installed in their place. Increase of capacity with the increase of height of the furnaces is, to a certain extent, inter-dependent with each other. It was necessary to have increased quantity of air and high pressures in order to smelt the sulphide materials. The higher pressure gives a higher smelting temperature in order to obtain hotter slags necessary to carry out the zincy material. Some authorities say that zincy slags are stiff slags, but if the heat obtained in smelting is sufficiently high, a very liquid slag is obtained, which causes very little trouble to furnace operators. Higher blowing pressures have the effect of producing hot tops in low furnaces, causing heavy losses of metals by sublimation. As Mr. Tourney-Hinde explained, the furnaces were heightened so that the sublimed metals would be condensed on the cooler upper part of the charge, and thus carried down again into the smelting zone. Increased height of furnace induced in its turn a further increase of blast pressure to give the necessary quantity of air required for rapid smelting.

In 1901, when I went to Port Pirie, 13 furnaces were engaged, and could not smelt the total quantity of concentrates at that time being produced by the Company's mine at Broken Hill. But on the introduction of the sintering process, and raising the blast pressure to 30-35 ozs., the number of furnaces was at once reduced to seven. Since then, with still taller furnaces, and still higher blast pressure, and other improvements, three or four furnaces are smelting the concentrates of three-quarters of the mines of Broken Hill.

It is always desirable to have a reserve supply of power so that the metallurgist can increase the pressure in order to maintain the flow of air to his furnaces if they get tight or sick, or, in special cases, to increase his quantity of air. In taking samples for pressure, it would be interesting if a pipe could have been inserted so that the pressures could be taken at the different vertical heights, but there would have been special difficulties in getting a pipe down to the zone in which the slag is forming. In lead smelting a certain proportion of slag is always mixed in the charge, and is the first constituent to melt out, and would prevent the insertion of a pipe to take blast pressures.

There is one point which Mr. Tourney-Hinde refers to, viz., by increasing the pressure 45-50 ozs., slightly more air would be forced in. The flow of air under conditions like that is rather difficult to calculate; but I think in this case the total quantity of free air forced in would be about 14 or 15 per cent.; the air under the extra pressure would also have an increased energy of chemical combination.

It is well known that in a furnace of given height and charge, the speed and general smelting conditions will vary with variations in the quantity of air supplied to the furnace.

I have very much pleasure in seconding the vote of thanks to Mr. Tourney-Hinde for his very interesting paper. (Applause.)

Mr. T. M. Goodall said: Mr. Tourney-Hinde's paper has been of very great interest to me, and I should like to have heard more about the treatment of zinc. I have always understood that presence of zinc in silver-lead ores has made a rather complex question and expensive treatment. Mr. Tourney-Hinde said that the Ashcroft treatment cost £80 to produce a ton of zinc. Am I to understand that after the separation of the lead and the zinc, the zinc concentrates are smelted in a similar manner to the lead?

Mr. Tourney-Hinde: No.

Mr. T. M. Goodall: Is the present treatment of zinc and lead a payable one at the normal prices of metal?

Mr. Tourney-Hinde: Yes.

Mr. T. M. Goodall: I should like to have heard more about the treatment of zinc and the comparative costs of the Ashcroft and present method of separation.

The Vice-President (Mr. D. F. J. Harricks): Before conveying to Mr. Tourney-Hinde the vote of thanks accorded him for his interesting paper, I should like to add that I think it has been particularly interesting just now, seeing that it referred rather fully to the mining industry, in addition to containing much of engineering interest to us. It certainly came somewhat as a surprise to me (as perhaps it did to others) to notice the relatively large proportion of zinc that is obtained from the Broken Hill ores, and it must also have been of great interest to Mr. Tourney-Hinde to have been associated with a company which had to evolve methods of a more or less original nature to deal with the class of ores handled at Cockle Creek. It was no doubt of interest to everyone to have observed the bold steps that were taken to obtain suitable blowing engines after, as Mr. Tourney-Hinde said, the Company had obtained prices from both European and American firms. Owing to these being considered high, the Company decided on a course which would stand very much imitation—they got their engineer, Mr. Tourney-Hinde, to design suitable engines, and had them made at Mort's Dock. It is very gratifying, I am sure, at the present juncture to be reminded of the possibilities of our local industry, and it must have been most gratifying to Mr. Tourney-Hinde to have seen the great success that has attended the working of the engines. I am sure that we should enjoy some further remarks on the novel features of these engines, and I would like him to tell me what was their overall efficiency.

I am sure that he will be quite prepared to give the figure, and it will be interesting, because the engines were made 12 years ago. At that time engines of this kind were practically the only ones in use—that is, for high pressures, the turbo blower not having been developed. The ordinary rotary blowers, viz., the Root's and the Baker blowers, really cease to be effective at even moderate smelting furnace pressures. It is not rare, as the author stated, for pressures of 90 to 100 ozs. to be used now, and the rotary type of blower becomes really inefficient at these pressures.

In a paper recently read before this Association, it was shown that these blowers rapidly lost their efficiency with pressures above 8 to 10 ozs., so that for the mining industry they have almost ceased to be used. In ordinary foundry practice, where lower pressures are required, the rotary blower seems to do reasonably well, and will always command a big field. I think that one of the things that struck members most on our recent visit to the Newcastle Steel Works was the type of blowing engine in use. Many were amazed at the huge reciprocating machinery when they had been previously informed of the exceptional heavy cost of the piling and foundations the nature of the ground required. I can appreciate that the reciprocating blower lends itself more readily to the conditions of regulation of speed and pressure required, but if Mr. Tourney-Hinde has had any experience in this respect, I am sure we would be glad to hear from him.

I should like him also, if he will, to describe the class of fire brick he used in his furnaces, and to tell us whether he has had comparative trials of local and imported makes; and perhaps he would be good enough to tell us where the local make was obtained from. I understand, from my own experience of lime kilns, that it is not altogether resistance to fusing that is necessary in a good fire brick; they have to resist to some extent the abrasive action of the material falling through the furnace.

Coming to the main feature of Mr. Tourney-Hinde's paper, which deals with the question of the best diameter for tuyere opening, I think the conclusions that the author has postulated to-night are really not open to very much criticism. I cannot understand anyone, particularly an engineer or a metallurgist, having the idea that there is practically no pressure in the furnace zone; I think I have interpreted Mr. Tourney-Hinde's remarks in that respect correctly—that is to say, the pressure in the smelting zone of the furnace to be practically the same as the atmospheric pressure outside. If that were the case, which is really impossible, it would justify the suggestion that stream lines were set up by the jet action of air delivered from the tuyeres, and in which case the size of the tuyere would be of importance. It is surely obvious, however, that in order to account for the energy put into the air, that a very great amount of resistance must be set up in the furnace, and that it is created by the material in the shaft of the furnace, and in the furnace proper. It would obviously be only a matter of waste energy to try and force the air through small tuyeres if larger ones would satisfactorily deliver the quantity of air required, and there were no mechanical objections thereto.

Referring to Mr. Tourney-Hinde's remark that small annular rings were fitted into the larger tuyeres, I should like him to describe how the rings were fitted, and whether, when fitted, they set up sharp turns or shoulders in the tuyeres. It is surprising to me, in view of the fact that the difference in pressure between that in the large tuyeres and in the furnace was so little, that there was a loss of 10 per cent. when the smaller tuyeres were in use, and this would seem to point to the fact that there was an unnecessary amount of restriction in the tuyeres. Were the tuyeres, when altered, of similar design to the large ones —that is, of conical form? The author will appreciate the effect on the co-efficient of discharge from the smaller orifice if this was not well designed. It also occurs to me that if there was any mechanical advantage in the smaller opening, by the adoption of the Venturi law, and the fitting of converging and diverging shaped nozzle tuyeres, the same quantity of air could be passed through a properly designed two-inch nozzle, as through a plain or slightly conical three-inch one. As, for instance, there is the Venturi meter, in which we know that the pressure energy, by increased velocity, is converted into kinetic energy to such an extent that at the throat of the meter there is no lateral pressure whatever. Again, in the Hopkinson-Ferranti steam valve, there is the same idea, the valve being only one-half the diameter of the steam pipe, and yet it passes practically the same quantity of steam through with an infinitesimal loss of pressure.

Problems of the nature described by the author are recurring constantly in works, on both the chemical and engineering side of the house, and from the author's remarks I think we can take a lesson which is one of importance to us as engineers, and that is, that a practical insight into chemistry, as it affects the engineer, is now almost essential for the complete education of the engineer; the value to an apprentice who has had the opportunity of spending his early years, or some part of his apprenticeship, in the laboratory of an engineering establishment, is very great indeed. He can then get some idea of the methods of analysing the materials he comes in contact with.

If our nation is to maintain its leading position in the industrial world, we must devote far more attention to scientific research, and increase the degree to which we can bring scientific knowledge to bear on all the problems of manufacture. We must do so if we are to effectively throw off the yoke of foreign influence in some of our industries. The establishment of laboratories for industrial research in the great industries, such as that of mining, is most important in this respect. I look forward to the establishment of Bureaus of Science, such as the Federal Government are now proposing to set up, and if such do become facts, it is to be hoped that the administration will be so organised as to at all times include for a strong factor in the control being drawn from the captains of private industry.

I have much pleasure in conveying to Mr. Tourney-Hinde the vote of thanks for his very interesting paper, and I will now call on him to reply.

Mr. Tourney-Hinde, in reply, said: I did not expect that so short a paper would raise such a discussion; I have nearly two columns of notes to reply to—almost sufficient in themselves to form another paper. I will, however, try and briefly reply to the salient points which have been raised.

Mr. Sinclair has raised the question of cold or heated air. In the lead smelters in which the experiments were made the air was of atmospheric temperature. There is, no doubt, a considerable advantage in pre-heating air where the conditions warrant it; it is not, however, usually carried out in connection with lead smelting; it is common enough in iron smelting, and in some copper smelting plants. Mr. Sinclair also referred to water jackets, and wondered what function they fulfilled. I might say that the temperature in the smelting zone is far above that necessary to melt cast-iron or brick—in fact, everything that is fed into the top furnace can only be got out in liquid form through the tapping holes, which indicates that the temperature is high enough to melt most materials. A fire-brick construction surrounding the smelting zone would therefore fail in a comparatively short time. To overcome this, cast-iron jackets, through which cooling water is constantly flowing, are used. The cooled iron surface causes some of the liquid slag inside the furnace to solidify on the inner side of the jacket, and this forms a protective coating. Mr. Sinclair also asked if it is possible to observe the interior of the furnaces? That is just the one thing you cannot do, and it leads to an enormous amount of speculation and guessing as to what goes on. Unfortunately, similar chemical operations carried on on a minor scale in the laboratory do not conform to the same re-actions as those carried on in the furnaces. As an instance, an assay may return so much lead, so much silver, and so much gold. In the smelting operation on the same ore the quantity of gold recovered is usually higher than that which can be shown by the most careful analysis, whereas the recovery of some other metals, such as lead and silver, is usually below that which ought to be recovered as shown by the same analysis. The cause is not altogether clearly known. Referring to the low velocity of the air in the blast pipe, mentioned by Mr. Sinclair, I would point out that it is usual to have a blast pipe supplying the air in most smelting installations of a very large diameter, so as to keep the losses from friction low. In the plant referred to in the paper, the diameter of the pipe immediately around the furnace would not be more than about 2 feet, and the main blast pipe supplying this would be about 6 feet in diameter. With regard to the remarks Mr. Sinclair made concerning the humidity of the air, there is no doubt that the condition of the air would vitally affect combustion, but up to the present it has not been the general practice to dry the air. The effect of humidity in the air may be observed in firing an ordinary boiler, and it is one of the principal reasons why a furnace fire burns less freely on a heavy, muggy day, and is, as members are aware, due to the quantity of uncondensed vapour held in the air. Under normal conditions, in lead smelting, it requires about one ton of coke to smelt one ton of charge—that is of the weight of the ores and fluxes taken together.

Mr. Poole referred to the width of the Port Pirie smelters, and mentioned that they were of greater width than the furnace shown on the screen. I do not wish now to discuss the width at the tuyere line of lead smelters—it is a very vast one, and is outside the scope of the paper.

Mr. Poole also referred to the practice of having a separate blowing engine to each furnace. That is the question for the metallurgist, and not for the engineer; but, with ample blowing power and large blast mains, the proper distribution of air to a number of furnaces should not be difficult.

Mr. Poole also stated that *quantity*, not *pressure*, of air, was the ruling factor. This is so; but the quantity supplied is generally dependent on the pressure available. His reference to experiments in closing the outlet of a "Green" blower in order to ascertain the slip, is also interesting, and I may mention that I have done the same thing, and, at times, with worn blowers, have obtained remarkably low efficiency, as low as 17 per cent., showing that for high blast pressures this type of apparatus is quite unsuitable.

With reference to Mr. Poole's suggestion to obtain pressures at various points up the shaft, I would point out that it is impossible to determine these, for the obvious reason that the shaft is enclosed in heavy brick work, and on the inside of the walls there is continually forming a crust of slag.

Mr. Goodall referred to zinc smelting. Zinc smelting is quite outside the scope of the present paper, which only set out to describe some experiments in the supply of air to lead blast furnaces. Zinc smelting is a different operation—it is a distillation process. Zinc ore, in a sense, is not smelted at all, but it is raised to a sufficiently high temperature to evaporate the zinc contained in it, and the zinc vapour or steam is carried from the retorts into fireclay condensers at a lower temperature, where it liquifies.

Mr. Harricks made kindly reference to the locally-built blowing engines as against imported ones. The best price at which we could get suitable engines landed here, i.e., an engine of similar capacity, is about £3,400. At that particular time things were somewhat slack in Sydney—most engineering works were very keen on competing for any work going on. The Mort's Dock Company's price for the two engines was £1,928—say, roughly, £2,000 against £3,000. I do not think they made very much out of the contract.

In reply to Mr. Harricks' question as to the efficiency of the blowing engines, I cannot state the figure from memory. I do not know whether Mr. Harricks requires the relation between the energy in the air delivered as against the power taken by the motor—I cannot give him that. Indicator cards takn show the typical blowing engine diagram, viz., about 85 per cent. The following figures may perhaps assist:—To run the engine empty with free outlets, the motor required about 50 amperes at 250 volts, and at full load it would take about 500 amperes.

Mr. Harricks further asked why turbo-blowers were not used on smelting works, and why preference was given to piston blowers? The reason is this: the turbo-blower is merely another form of centrifugal blower, and, like all blowers of that type, they have only a limited range over which they can work efficiently. At some particular pressure they are efficient machines; below that, or above that (it is very difficult to get anything very much above it, as a rule) efficiency falls off very rapidly. The metallurgist requires a machine with a considerable range of pressure, and there does not appear to be the same elasticity about the turbo-blower as there is with the piston blower.

Regarding the quality of fire-brick used in the construction of a lead blast furnace, strange as it may perhaps seem, it does not require very highly refractory fire-brick. The fire bricks that were used were locally made ones—some came from works round Sydney, some from Melbourne, and some we made ourselves. The reason is that slag forms inside the surface, and forms a protective coat in itself.

Upon the part of the shaft where the temperature is insufficient to form slag, the principal wear is that due to friction of the material descending the shaft. In the crucible, density is quite as important as fire-resisting quality; and the necessity for density is to prevent leakage of the molten metal through the brick.

The shape of the annular nose pieces inserted in the tuyeres was so formed that they fitted inside the conical tuyere; they were about 3 inches long, and had a conical hole through them, the inner end of the cone being the same size as the interior of the tuyere. The frictional resistance would undoubtedly be greater than it might have been had the tuyere been re-designed so as to have a straight line from the air entrance to the air exit. I am afraid designing them according to the Venturi law is not practicable, because the outlet from the tuyere is continually being changed by the material being smelted passing the opening.

I quite agree with Mr. Harricks that chemical knowledge on the part of the engineer is a great asset—it helps him to understand the chemist, or the metallurgist, in coping with their difficulties, and it enables him to discuss in a reasonable and logical manner the troubles he would not otherwise be prepared to discuss, simply because the chemist does not put them to him in engineering language. No doubt the Science Bureau, to which Mr. Harricks referred, if properly conducted, will be an inestimable advantage to engineers, and to the country as a whole, because the manufacture of any article, no matter how simple, can usually be facilitated by a proper knowledge of chemical laws, as well as engineering laws.

I do not think there are any further points to which I have to reply, and I thank you all very much for the vote of thanks, and for the very patient hearing you have given me to-night.