The Author. whether some of the valves were not moved mechanically. He thought this had been found necessary.] Both systems were at work. As to the collection of the gases, there was always considerable air-pressure in the furnace, and that seemed to be sufficient to send them through all the coolers, fans, pipes, etc. It should be remembered that there were now engines aggregating about 100,000 HP. at work on the Continent with cooled and purified blast-furnace gases. In answer to Mr. Beaumont's question as to the pressure of explosion and the average pressures of the indicator-diagrams, large-scale indicator-diagrams would be found in Mr. Hubert's report referred to in the Paper, which was issued by the Société Cockerill.[1] With regard to the benzine vapour, he had seen the engine started, and he presumed the vapour was pumped into the cylinder, but he was not quite certain. Referring to a model of a single-acting blowing-engine cylinder exhibited by Mr. B. H. Thwaite, the Author remarked that on the Continent double-acting blowing-cylinders were preferred. He was extremely obliged to the members for the kind reception they had given to his Paper.

Correspondence.

Mr. Booth. Mr. W. H. Booth remarked that, to those engineers who were familiar with the history of the utilization of blast-furnace gas for motive-power purposes, the Paper savoured somewhat of the play of "Hamlet" with the Prince of Denmark left out; for there was very little recognition of the originator of the whole movement, the Englishman, Mr. B. H. Thwaite, and a great deal of the foreigner, who had only come in after Mr. Thwaite had made public his own researches. Some time in 1894 Mr. Thwaite had spoken to him on the subject, had noted the similarity between his producer-gas analyses and the analyses of many waste gases from blast-furnaces, had synthesized a gas to the blast-furnace quality, and had proved by actual trial that it would run faultlessly in a gas-engine. Hence had arisen the installation of the plant at Wishaw, which had run in its original form ever since, lighting the ironworks. He had made the first independent test of it in August 1896, and the Author was in error in stating

[1] In the publication referred to in the foot-note to p. 37.

Mr. Booth.

that some difficulty had been found in starting. There had been no difficulty in starting, and no such words occurred in his report. On the day when the power-tests had been made, the gas coming off had been of very poor quality, but no analysis had been made. Mr. Galbraith, however, had made the three analyses mentioned in Mr. Booth's report, which had shown that the calorific value of the gas varied between 99 B.Th.U. and 117 B.Th.U. per cubic foot; and it was probable that the tests had been made with gas nearer the lower figure: certainly the gas had not had the calorific value of 126 B.Th.U. mentioned in the Paper, nor did he see how this figure could have been obtained from his report. It was quite an error to suppose that gas from a coal-fed furnace was richer than gas from a coke-fed furnace. In matters like this it was impossible to go behind the analysis, and analysis showed that the Wishaw furnaces gave poorer gas than the coke-fed furnaces of the Frodingham works. The gas coming off at Wishaw might be better, but he was referring, of course, to its condition as issued to the engine after it had had the ammonia and tar removed by the residuals plant. Much weight could not be given to the statement that Mr. Lürmann had recognised the value of blast-furnace gases in 1886; at least, that gentleman did not appear to have set much value on his own opinion, for in 1898 he had strongly opposed the idea of their utility as a source of motive power. The first person to recognise that blast-furnaces produced a useful gas had been, Mr. Booth believed, Neilson, of hot-blast fame, in 1828, the year in which the blast-furnace had been blown out in Sussex. Producer-gas had not even been used in gas-engines before the early eighties, and it was certain that the first recognition of blast-furnace gas for power-production had been that by Mr. Thwaite, which had been published soon after by him,[1] and had become known to the Belgians and to others. While no credit could be awarded to those who had endeavoured to deprive Mr. Thwaite of credit, he thought the reverse might be said of the iron-masters of the Continent who had recognised the merit of Mr. Thwaite's invention, while English iron-masters had practically ignored the economy to be received, despite the successful running of the initial Wishaw plant during the past 6 years. The question of dust was very important, and Mr. Thwaite had realized from the first the necessity of purifying and cooling the gases. The utility of this had been denied by the Belgian engineers, and the Author seemed to have become imbued with the same idea. The dust of

[1] *Iron and Coal Trades Review*, 16 November, 1894.

Mr. Booth furnace-gas consisted of lime, fine coke, and ore-dust. The heavier portions settled by gravity, but a final filtration was necessary if gas-engines were to run for any length of time without undue wear and friction. Cooling the gases, if well done, assisted to remove dust, and it was essential to cool the gas to deprive it of its moisture, for, as was well known, moisture in a gas-engine caused serious diminution of power. It was, he felt confident, bad practice to neglect cooling and filtration, especially as the gas could be cooled in the economizer type of cooler, thereby heating the air flowing to the furnace from the blast-engine. In this cooler, as proposed by Mr. Thwaite in his Paper read at the Engineering Conference at Glasgow in 1901, the cooling-tubes were kept clean by scrapers, which pushed down all dirt and dust, and at once drowned the lime, which otherwise would tend to set. In view of the full utilization of the waste gases Mr. Thwaite proposed to heat the blast-stoves by means of producer-gas, free from the lime dust which rendered the ordinary stoves so very inefficient, but this opened out too wide a field for further discussion. It might be added to the record of the Wishaw test that the consumption of gas included that necessary to drive the supply- and circulating-fan. The engine had then been doing considerably more work than was shown by the electrical instruments, the fan being looked on as part of the engine. This fan helped to purify the gas, its capacity being five times what was actually needed. It thus circulated the gas through the holder, and was therefore superior to the complications involved in the use of two or more fans in sequence. The neglect of obvious economies in this country was strikingly manifested at the new power-station of the Midland Power Distribution Co., at Ocker Hill, near Tipton. This large station, provided with steam-boilers to use coal, was in the midst of a district of blast-furnaces capable of supplying many similar power-plants. It was very difficult to make men believe that blast-furnace gas would burn in a gas-engine. The gas was of such a dilute nature that sometimes it would hardly burn under a boiler; therefore, it was argued, it could not be satisfactory in an engine. These objectors entirely overlooked the effect of molecular approximation which followed on compression of the gaseous charge. Such compression caused the poorest gas to ignite readily.

The Compagnie Française des Moteurs à Gaz et des Constructions Mécaniques. The Compagnie Française des Moteurs à Gaz et des Constructions Mécaniques, of Paris, pointed out that a number of large gas-engines had been constructed on the Otto system by the Gasmotoren-Fabrik Deutz since those mentioned by the Author, notably two 1,000-HP. engines for Dudelingen and Hörde, respectively. At the present time three engines of 1,000 HP. and others of 600 HP. and 500 HP. were under construction. Installations of Otto engines had been made for the generation of three-phase electric current, the engines running in parallel, as, for instance, at Dudelingen and Friedenshütte, where the variation of speed was $\frac{1}{150}$. The Compagnie Française des Moteurs à Gaz et des Constructions Mécaniques.

Mr. W. HAWDON, of Middlesbrough, remarked that, taking the Author's figures of 162,000 cubic feet of blast-furnace gas per ton of iron made (although in making Cleveland iron it was found to be about 156,000 cubic feet) and the surplus gas as being 37,000 cubic feet, which seemed to be approximately correct, there would be obtained with a furnace making 1,000 tons per week (or, say, 6 tons per hour)— Mr. Hawdon.

$$\frac{37{,}000 \times 6}{123} = 1{,}804 \text{ HP.-hours}$$

from the spare gas; and this when using a portion of the gas under boilers for driving the blowing-engines: and as the process was continuous, there would appear to be about 1,800 HP. to be obtained from a furnace making 1,000 tons of pig-iron per week.

Mr. E. KÖRTING, of Hanover, remarked that Messrs. Körting Brothers used compression up to 13 atmospheres with power-gas and 10 atmospheres with lighting-gas, owing to special arrangements in the combustion-chamber to reduce the high temperature of the compressed charge. Consequently the thermal efficiency reached 33 per cent. by brake horse-power and 38 per cent. by indicated horse-power, and they had been able to run two engines of 125 HP. at the Mansfelder Gewerkschaft with gas having a calorific value of only 629 kilogram-calories per cubic metre (71 B.Th.U. per cubic foot); they had offered lately engines for gas of only 520 calories per cubic metre (58 B.Th.U. per cubic foot), and were confident that these would prove successful. The new double-acting two-cycle Körting engines admitted of being forced in the following sense. The combustible charge of four-cycle engines was not greater than 80 per cent. of the volume displaced by the piston, whereas in the new engine, which was designed to run normally with a charge of also 80 per cent. of the volume displaced by the piston, they were enabled to increase the volume of the charge up to 115 per cent., which meant an increase of power of at least 50 per cent. on normal power. They constructed their engines with a gear to modify the time of ignition in reference to the dead-point position, and therefore they were able to run the engines as slowly as they pleased with the same good result, and, in fact, with the same Mr. Körting.

Mr. Körting. diagram, as if the engine were running at normal speed. There was no difference in this respect between a steam-engine and a gas-engine, if only the required steps were taken to change the time of ignition. If the combustion-chamber was properly constructed and provided with suitable means for reducing the temperature of the compressed charge, there was no danger of premature explosion, even with the largest cylinders.

Mr. Lürmann. Mr. FRITZ W. LÜRMANN remarked that he had drawn attention in 1886[1] to the advantages of the use of blast-furnace gases in gas-engines.

Prof. Meyer. Professor E. MEYER, of Charlottenburg, in regard to the relative advantages of single- and multiple-cylinder engines, agreed with the Author and Professor Witz that complete experiments with a large four-cylinder engine, comparable with those carried out under the direction of Mr. Hubert with the Société Cockerill's single engine of 600 HP. at Seraing, were much to be desired. In such trials, in addition to the determination of the indicated and electrical horse-power, the use of a reliable brake was essential in order to obtain data for the comparison of the mechanical efficiency of the two types, as on this important question information was entirely wanting, not only with gas-motors but also with steam-engines; that was, it was not known to what extent multiplication of the number of cylinders increased the frictional loss, and so neutralized in part the saving of steam per horse-power-hour. On the other hand, he considered that the question which class of engine might be most advantageously adopted could not be solved by such experiments, as that was not dependent upon the gas-consumption, which, according to his view, would be nearly the same in either case, supposing both engines to be equally well designed and constructed. The choice in such cases would be governed mainly by considerations based upon constructive details, price, degree of uniformity of speed, etc. For certain purposes the single-cylinder engine would probably be indicated, while for others, especially where a high degree of uniformity in running was necessary, the multiple-cylinder type would probably be preferred. It was therefore easily conceivable that both kinds might justify their combined existence side by side. In other words, the question of preference was to be decided rather from the results of experience gained in the drawing-office, the shops and in actual work, than from the most exact determinations of useful mechanical effect alone.

[1] Zeitschrift des Vereines deutscher Ingenieure, vol. xxx. p. 704.

Mr. MAX MÜNZEL, of Mülheim-on-Rhine, remarked, with reference to the statement that the advance of the gas-engine limit from 10 HP. to 1,000 HP. had occurred between the years 1895 and 1900, that, as far back as 1891, a twin engine of 120 HP. had been at work at the central electric-lighting station in Dessau, with cylinders 500 millimetres (19·7 inches) in diameter and 760 millimetres (30 inches) stroke, making 140 revolutions per minute. The fact that increase in cylinder-dimensions had been realised but slowly was to be attributed to the circumstance that, at that time, lighting-gas had been used; and, with this, difficulties had been encountered with the engine in question, owing to premature ignition and consequent sudden reduction in speed of the motor, which it had been possible to remedy only by cooling the outlet-valve by a water-injection in the exhaust-pipe. The valve, being placed on the side of the cylinder, could not be cooled by the incoming current of gas and air. That heating-gas of a lower calorific value gave less trouble in regard to this particular difficulty had only become generally known with the extension of the use of Dowson gas; previously there had been no reason for experimenting on larger cylinders, not merely on account of the increased risk, but also from the high price of the fuel, which it had only been possible to employ advantageously when the consumer had had his own gas-works, so as to obtain the fuel at the cost of production. With the recognition, however, of the fact that blast-furnace gas could be equally well used for direct generation of power, increase in the size of the engines had followed very rapidly, the most notable advance being that made by the Société Cockerill from 200 HP. to 600 HP. in a single cylinder. This class of engine, of which a considerable number had been made, had a cylinder 1,300 millimetres (51·2 inches) in diameter and 1,400 millimetres (55·1 inches) stroke, or a ratio of stroke to diameter of 1·08 : 1, which had not previously been used in gas-engine construction. According to the information which had reached him from Differdingen, this combination of large diameter with comparatively short piston-stroke had given rise to difficulty from leakage which could be met only by liberal use of the best viscous cylinder-oil. About a year ago, in conversation with the Author, he had expressed the opinion that 250 HP. in a single cylinder 850 millimetres (34 inches) in diameter, was the maximum advisable with blast-furnace gas. This view had been based upon the then existing want of experience of the working of large engines for prolonged periods, and the fact that the difficulty of keeping the piston tight was, as every builder of gas-engines knew, notably Mr. Münzel.

Mr. Münzel. increased by increase of the cylinder-diameter. The principal reason, however, against the use of single-cylinder engines of large power was the necessity of using an excessively heavy fly-wheel, even when only a moderate degree of regularity in running was required. In a single-cylinder 600-HP. engine, with the ignition controlled by a hit-and-miss motion, it was even worse; as this method of governing, in conjunction with a low number of revolutions per minute, resulted in such irregular working as to be inadmissible for ordinary purposes, and sufficed at most for pumping- and blowing-engines. As it was not feasible to equalize such irregularity by the use of heavy fly-wheels, owing to the impossibility of bringing the necessary weight into the rim of the wheel, the above limit of 250 HP. was considered to be sufficient, as the requirements of the smelting-works were entirely for driving alternating-current dynamos with a maximum duty of 1,000 HP., but with such a degree of uniformity as could not be obtained by hit-and-miss governing. Even for a blowing-engine he considered it desirable that a variation of 50 per cent. in the number of revolutions should be attainable without prejudicing too greatly the uniformity of working, and therefore that a two-cylinder engine was best suited for such work. When the exhaust-valve was placed low down, which was undoubtedly advantageous for the expulsion of dust, there was a corresponding disadvantage in the tendency of the lubricating-material of the cylinder to follow the same path, so that the piston might run dry unless provision was made for continuous heavy lubrication. In order to secure the latter conditions it was therefore desirable that the exhaust-valve should be placed at a higher level, which further required that the gear should be as perfectly cleaned as possible to prevent the accumulation of dust in the cylinders and valve-boxes. In this respect the use of fan blowers with water-injection for gas-cleaning, first adopted in practice on a large scale at Dudelingen and at Differdingen, was a very important advance towards facilitating the direct use of blast-furnace gas in motors. At the Gutehoffnungshütte at Oberhausen, where there were at work six Otto gas-engines, collectively of 2,200 effective HP., this system of wet centrifugal cleansing had been subsequently introduced, with the result that the gas-mains which had formerly required cleaning at intervals of 14 days at most now ran for more than 6 weeks without calling for any special attention. With regard to governing, the best method of working was to keep to the full Otto cycle without cutting out ignition, the engine taking in air and gas in the same proportion at all loads, Mr. Münzel.

but at a lower compression as the load diminished. Electric ignition, in his experience, gave excellent results at all loads, in respect of both gas-consumption and uniformity of running. For the starting of large engines compressed air was to be preferred to benzine vapour. If, as usually happened when the engine was cold, the valves and pistons were not quite tight, part of the inflammable mixture in the outer case would escape during the compression period on the return stroke of the piston, so that the charge might not be strong enough to start the engine with the impulse of one ignition, with the result of a sensible loss of time on the expulsion of the burnt gas, until the cylinder was ready for a new charge. With compressed air this difficulty was overcome, for if one impulse was not sufficient, the automatic compressed-air valve gave a second or third, and the motor in all cases started with the regularity of a steam-engine in a few minutes. There could be no doubt as to the number of cylinders to be used under present conditions. With alternating-current generators running in parallel in a central station, single cylinders were impossible except when the dynamo was belt-driven, which excluded their use for large power-units. The conditions were fairly satisfied with twin Otto-cycle motors, but more easily and perfectly with four-cylinder engines. Twin motors coupled in parallel were in use at the Friedenshütte works, and others with four cylinders at Dudelingen. When uniformity of working was not specially demanded, the single-cylinder engine might be preferred on the ground of greater simplicity in construction; but here it might be noted that the original outlay in working-cost was about the same for all classes, whether with one, two, three or four cylinders. An advantage of the single-cylinder engine was to be found in the smaller number and more ready accessibility of the moving parts requiring lubrication, giving lighter work for the engine-room attendant; but in this respect twin engines with cylinders side by side would be about on an equal footing for similar power. As it was now a well-established fact that a notable economy was obtainable in ironworks by the direct use of gas without the intermediate agency of steam-boilers, further elaborate experiments on gas-consumption seemed to be unnecessary. The consumption of a few cubic feet more or less per effective horse-power-hour was a matter of small consequence. More important, however, was the question of the suitability of the engine for the conditions of long-continued work called for in ironworks, and in this respect experience alone could decide as to the best form. As regarded economy of working and

Mr. Münzel. price, the different systems in use at the present day—the Otto, Oechelhaüser, Simplex and Körting systems—were substantially of equal value, and it was to be expected that the combined experience of smelter and engine-builder would result in the development of a type combining all the best points of the existing systems. As supplementing the information previously given, it might be stated that at Hörde, to the four Oechelhaüser 600-HP. engines, an Otto motor of 1,200 HP. had been added, and another of the same size was in course of erection. At the Höesch works in Dortmund two 300-HP. Otto engines were supplied directly from the blast-furnace gas-main without an intermediate gas-holder, which latter item he considered to be unnecessary when the gas-conduits were of sufficient length and diameter. The degree of compression to be adopted for gas in proportion to its calorific value was a matter of considerable importance, especially as regarded prevention of premature ignition. The compression-space should be as simple in shape as possible, and with a minimum ratio of surface to capacity, which pointed to the use of a form as nearly spherical as might be. With such an arrangement the necessary degree of compression to be used might, according to his experience, be found by the empirical formula

$$C = 5 + \frac{8{,}000}{H}$$

where C = compression in atmospheres (absolute),
H = minimum calorific value per cubic metre in kilogram-calories,[1] as determined by the Junkers calorimeter.

Taking $H = 1{,}000$ the above gave as the most advantageous degree of compression, $C = 13$ atmospheres absolute; or 12 atmospheres, or 170 lbs. per square inch, excess pressure. The recent development of the waste-heat power-engine, in which an auxiliary engine was driven by sulphur-dioxide vapour evaporated with the surplus heat of condenser-water, placed the large single-cylinder gas-engine in another light. If the heat of the exhaust gases and the jacket-water were to be applied to the evaporation of sulphur dioxide in the same way as had been done successfully by Professor Josse in Berlin with the steam-engine, a double-acting low-temperature vapour-engine could be attached to the crank-shaft of the gas-motor, with the result of considerably improving the regularity of rotation, and realising about 33 per cent. additional power; or

[1] If the calorific value be expressed in British thermal units per cubic foot, h, the formula becomes $C = 5 + \frac{903 \cdot 2}{h}$.

in other words, a 600-HP. engine would develop 800 HP. for the same gas-consumption, and the thermal utilization would be raised to between 35 per cent. and 40 per cent. by the combination. A further advantage in such a combination would be found in the diminished weight of fly-wheel required to attain uniformity, and it would therefore be admissible for driving central-station alternators. The question of whether single- or multiple-cylinder gas-engines should be used must decidedly be answered in favour of the former. The working of waste-heat engines, however, required a very large supply of cooling-water, amounting to 300 litres per horse-power for a difference of 10° C. between the temperatures of injection and discharge. The method advocated would therefore be possible only where condensing-water was readily obtainable. Further information on the subject was to be found in a pamphlet entitled, "Recent Experience and Tests with Waste-Heat Engines," by Professor E. Josse.[1] Mr. Münzel.

Mr. P. M. PRITCHARD considered that somewhat undue prominence was given to the efficiency of gas-engines using blast-furnace gases, considered as heat-motors. Where, as in large ironworks, there was in the waste furnace-gases practically an unlimited supply of power to be drawn upon, the first consideration was to build an engine which would be entirely free from breakdowns, and which could be relied on to run continuously for any length of time. This was particularly true when the engine was utilized for meeting a continuous demand for any form of power, whether as electric energy or as the power required by a blowing-engine. The tests made by various authorities and cited by the Author were valuable as showing what might be done in the direction of economy, but they did not give any information as to the mechanical efficiency and reliability of the engines tested. Although it was not to be expected that the makers would supply working-drawings of any of the engines which they had built, for publication in the Proceedings, yet it would be of interest if the Author could put before the Institution a log of the running of some of these large engines over an extended time, giving full details of the running, and mentioning defects, if any, which had developed, with their cause and remedy. His attention had been attracted to this matter owing to the apparent reluctance of engineers responsible for the design of large power-stations to adopt gas as their motive power, a reluctance which was all the Mr. Pritchard.

[1] Mittheilungen aus dem Maschinen Laboratorium der Kgl. Techn. Hochschule zu Berlin. See also Minutes of Proceedings Inst. C.E., vol. cxlvii. p. 467.

Mr. Pritchard. more remarkable in view of recent developments in the methods of recovering by-products in gas-producing plant. Referring to the Seraing 600-HP. motor, the diameter of the shaft was given as 18 inches, with a cylinder-diameter of 4 feet 3 inches. This ratio contrasted strongly with the Westinghouse practice, which made the diameter of the shaft about one-half of that of the cylinder. There would appear to be considerable divergence in practice in this respect, and any information the Author could give as to standard practice would be acceptable. He had found that a shaft 10 inches in diameter was fully small for cylinders 20 inches in diameter using gas having a calorific value of 500 B.Th.U. per cubic foot.

Mr. Sauvage. Mr. E. SAUVAGE, of Paris, agreed entirely with the Author's statements. He believed there was little doubt that the use of blast-furnace gases in motors was attended with a real economy. Of course, for want of sufficiently prolonged practice, the cost of repairs could not as yet be computed with accuracy; it would be prudent to suppose that these expenses might be larger than for a plant consisting of boilers and steam-engines of equal power. It was hardly possible to say which was the best of the existing types of gas-engines for such work, principally the Otto, Simplex and Oechelhaüser. Probably but little practical difference would be found, the construction being carefully carried out in all cases: this condition appeared to be essential. The reason why the consumption of water was greater with large cylinders than with smaller ones, as stated at p. 19, was not obvious, and he wished the Author would give some explanation on this point. A few details of the fans with water-injection for purifying the gases would also be of interest.

Mr. Theisen. Mr. E. THEISEN, of Baden-Baden, considered the cleansing of blast-furnace gas by the joint action of a centrifugal fan and water-injection to be incorrect in principle and wasteful of motive power. In his method a centrifugal drum washer was used, in which the gas entering at one end was forced into contact with a thin film of washing water on the inner surface of the drum, moving in a spiral path from the opposite end. In this way very large working-surface was developed; for instance, in a No. 5 machine, with a cylinder 9 feet in diameter and 11 feet in length, making 300 revolutions per minute, an effective washing-surface of 200,000 square feet per minute was obtained. In one instance, where the apparatus had been continuously in use for more than a year, gas taken warm from the main with 3·6 grams of dust per cubic metre (1·6 grain per cubic foot) and 36 grams of water-vapour per cubic metre was purified to 0·01 gram of dust and 3 grams of water-vapour per cubic metre. In its latest improved form the apparatus had been applied in numerous instances on the Continent, and up to a maximum capacity of 1,400 cubic metres (49,000 cubic feet) per minute, as well as in England. It had also been applied to clean the chimney-gas from boiler-flues from dust, sulphur gases, soot, &c., with the additional advantage of giving an increased draught, whereby the evaporative capacity was increased by from 50 per cent. to 60 per cent. Apart from the direct use of the gas for power, there was great advantage in using it in a perfectly clean condition in blast-heating stoves, so as to do away with the stoppage for cleaning, whereby the stove plant might be reduced by two or three stoves per pair of furnaces, representing a saving in the cost of fuel of about £10,000. When compared with fans, the economy in motive power was considerable. Thus, in one large ironworks, where two fans, cleaning 210,000 cubic feet per hour and reducing the dust to 0·2 gram to 0·3 gram per cubic metre (0·09 to 0·13 grain per cubic foot), were in use, a motor of 110 HP. was employed. Recently the limit of dust had been reduced in the Theisen washer with 40 HP. to 0·004 gram per cubic metre (0·0017 grain per cubic foot). Such purity would not be obtained with fans, even if four fans and 160 HP. were employed. Mr. Theisen.

Mr. R. HANBURY WAINFORD, of Newcastle-on-Tyne, remarked that the subject was so exhaustively dealt with by the Author that there appeared to be but one question open to comment, viz., the separation of the dust, which was admittedly difficult to effect and somewhat expensive. Some account of his experience in this direction might be of interest. For many years before it had been found possible to use blast-furnace gases directly for motive power, finely-divided powders had been successfully separated from air travelling with high velocity in considerable volume. A tornado-like centrifugal action was induced, or large settling-chambers, into which dust-charged air was directed, were used; but one simple and compact method had given such satisfactory results that a brief description of it might be permitted. This was a rectangular box placed horizontally, and having several dividing partitions arranged internally, upon the sides of which were fixed projecting angles, causing the current to be directed from side to side, and in so flowing to strike against and to some extent whirl round the angles or baffling-plates, thus setting up an eddying action which rapidly precipitated the dust into a hopper or conveyor below. It had been found that the first series of baffling-plates collected the greater portion of the dust, Mr. Wainford.

Mr. Wainford. including practically all the heavy metallic particles; and, on sifting, the large proportion of impalpable dust also deposited was noticeable, tending to show that to separate in one operation was possible. The succeeding chambers had baffling-plates at varying angles and less frequently placed. The Author might remember conducting some coal-dust trials about 8 years ago, which had been carried out as indicated in Sheffield; possibly he had witnessed them, and no doubt he would agree that the results had been satisfactory. Many other materials of a lighter nature had been dealt with in like manner. The Author's observation that to prevent deposits of dust a gas-engine cylinder should be constructed without sharp internal angles or corners was founded on the same principle as the dust-separator mentioned above. It might be added that the velocity of the gases (29·5 feet per minute as a maximum) was not high, and therefore was favourable to this system. Some doubt had existed in his mind as to the necessity of cooling; the high degree of compression to which the gases were subjected had settled this point; and further, a reduction in volume was advisable. To meet these requirements with the box described, surface-cooling must be resorted to, it not being permissible to apply water direct for the purpose. The box offered ample surface which could be jacketed, and the water could be caused to circulate through hollow partitions. There were one or two objections to cooling by means of a spray as described in the Paper. It would be noted that care must be observed that too much water was not used, an excess of water causing the gases to lose in calorific-value, and as there were continual fluctuations both in quantity and temperature of the gases passing, it would appear to be almost impossible to arrive at a proper adjustment. There was also the objection of dust-water (smudge) to be urged against this system. In coal-washing operations, in order to recover the water in anything like a clean state for further use, settling-ponds of large area in duplicate or triplicate had to be used, and considerable cost attended the separation of dust. It might, therefore, be correct to assume that similar difficulties would be met with in the case under notice. The Author might be able to give some information upon the matter, and he was to be heartily congratulated on his Paper, as were also the pioneers in the development of a great system.

Mr. Wright. Mr. H. E. Wright, of Middlesbrough, remarked, in reference to the analyses of gases given in the Paper, that they all showed an excessive percentage of carbon monoxide compared with Cleveland practice, and also hydrogen was in some cases in excess of that

Mr. Wright.

obtained from Cleveland furnaces. A normal gas from these would contain about 10·5 per cent. of CO_2, 27·5 per cent. of CO and 0·75 to 1·25 per cent. of hydrogen. The gases described in the Paper showed an increased coke-consumption, and the power they would develop was greater than would be the case with the gas from a furnace worked economically in regard to fuel. The gas produced by furnaces using east-coast hematite was still poorer in combustible matter, the average amount of CO being found to be about 24 or 25 per cent., and these gases were saturated with water-vapour to the extent of about 10 per cent. of their volume. In consequence, it was found that the mean calorific value of the gas was lower than that stated in the Paper, and the normal figures for Cleveland gas or gas from east-coast hematite would be, Cleveland, 88 B.Th.U. to 105 B.Th.U., hematite, 78 B.Th.U. to 91 B.Th.U., without taking into account latent heat, etc. Owing to using less coke, experience in the works of Messrs. Sir B. Samuelson & Co. showed a less production of gas per ton of iron, normal figures for gas (dry at 0° C. and 760 millimetres pressure) being, Cleveland, 156,000 cubic feet, hematite, 147,000 cubic feet. The average quantity of dust stated in the Paper agreed in the main with his experience, viz., Cleveland, 1·35 grain per cubic foot (3·1 grams per cubic metre); hematite, 1·19 grain per cubic foot (2·7 grams per cubic metre). One-fourth of this dust was deposited in dust-catchers, one-half in the underground flues, and one-fourth passed to the boilers and stoves. The dust was not "metallic" at any stage; it consisted of fine burden, that was, fine mine-, lime- and limestone-dust, coke-dust and coke-ash. The following analyses showed the chief constituents of dust collected from furnaces smelting Cleveland ore:—

—	Insoluble Matter.	Alumina.	Lime.	Iron as Oxide.	Zinc Oxide.	Potash and Soda.	Loss on Calcination (Carbon & CO_2).
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.		
From dust-catchers .	18·2	10·0	8·9	20·1	12·0	..	18·5
From flues . . .	20·2	12·15	7·2	19·9	3·8	..	24·5
From stoves and boilers after combustion	14·3	10·00	12·0	5·95	10·44	13·44	23·55

[The absence of a reply to the foregoing Correspondence is explained in the foot-note at p. 1.—Sec. Inst. C.E.]