

ters in diameter. (Fig. 4.) Connections are made directly with the high pressure conduits for articles of very large size.

For blowing ordinary drinking glasses a special piping communicates with the high pressure cylinders through the intermedium of a mercurial regulator, which expands the compressed air to a pressure of 170 to 200 grammes per square centimeter. This piping, which is of cast iron and 125 millimeters in internal diameter, is suspended beneath the floor of the furnace hall. The air compressed to this degree is stored in 4 reservoirs of a capacity of 670 cubic decimeters. The total volume is 4,000 cubic decimeters.

Along this piping there are twenty coupling screws, analogous to those used on water pipes, which are arranged around the furnaces at the most convenient places. The proper working of the apparatus is shown at every instant by a high pressure gauge, and a water and an open leg steam gauge.

As a consequence of these arrangements, the different systems of piping can be kept under constant surveillance.

Distributing Apparatus.—The difficulty in applying blowing apparatus to the glassworker's tube resides in the fact that the workman is obliged to rotate the latter continuously in order to keep the piece of glass that is being worked in an axis that is sensibly the same as that of the tool that supports it. The position of this tube varies according to the kind of work being done; so, in order to satisfy such different conditions, we have constructed three types of apparatus to be used: (1) according as the workman is making the glass by revolving it according to a horizontal axis; (2) revolving it according to a vertical axis, the glass being under the tube; or (3) revolving it according to a vertical axis, the glass being above the tube.

These apparatus, moreover, are based upon the use of an air-pipe, into which the workman fits his tube, and of an automatically closing cock that he actuates either with his hand

square centimeter, and form objects having a capacity of from 2 to 1,700,000 cubic centimeters.—*Appert Brothers, in La Nature.*

A NEW PROCESS FOR THE SEPARATION AND RECOVERY OF THE VOLATILE CONSTITUENTS OF COAL.*

By T. B. LIGHTFOOT, M.Inst.C.E.

IN bringing the following paper before the members of the Society of Arts, my object shall be, first, to point out briefly the necessity that exists for some simple and inexpensive method of recovering the volatile products now almost universally lost in the coking of coal; then to describe the nature of the process recently invented by Mr. John Jameson, of Newcastle-on-Tyne, and the form of apparatus employed; and, finally, to give some particulars respecting the utilization of the recovered products, and some considerations as to the possible application of the system.

It will be premised that all here are acquainted with the general facts that coal consists of a solid or carbonaceous component, and a gaseous or chiefly hydrogenous one, and that the process of coking is undergone for the purpose of driving off the gaseous portion, and leaving behind an almost pure, solid carbon; also that the hydrogen, in being driven off, carries with it some carbon in combination; that part of the hydrogen, by combining with the nitrogen of the fuel, forms ammonia; and that some of the hydrocarbons, as well as ammonia, are, to a great extent, condensable at the ordinary temperatures, and form most valuable, and much sought for, articles of commerce.

Seeing then that this is the case, it surely must be a matter for surprise as well as regret that, at the present time, nearly the whole coke manufacture is carried on under such cir-

and ammonia, at present prices, a loss of some £2,300,000 a year, or about 5s. 6d. per ton of pig iron produced.

From this brief consideration, I think it will be at once conceded that a real necessity exists for a process in which the constituents of the coal will be economically separated and collected, so as to be used in the most beneficial manner. But, it may be asked, if the want is so great, has such a process not existed for some time, and are there not very good practical reasons to prevent its adoption, either on the score of deterioration in the quality of coke produced, or from some other cause? To this it may be answered that, during the last ten years, patents have been taken out for apparatus to accomplish the object in view; but in this country, at any rate, none of them have had extended application. It seems as if coke manufacturers were only now awakening to the fact of their want of economy, possibly because, in recent years, prices have been so low, and competition so keen, that profits have been cut down to the smallest possible fraction, if indeed in some cases they have not altogether disappeared. Another consideration of obvious importance, is that no process involving the entire rebuilding of the coking ovens, or even their alteration to any great extent, was likely to obtain speedy adoption, for all manufacturers are naturally averse to a wholesale replacement of their plant, which means a large increase in capital invested, and upon which interest must be paid.

Looking at the various processes patented for the recovery of the volatile products, prior to the working out of Mr. Jameson's plan, it may be stated that they all involved the use of close ovens, and were of two distinct characters, viz., those in which distillation was to be carried on in an oven or retort, externally heated by the gas after being deprived of its more easily condensable constituents, and those in which the gas was to be used inside the oven itself over the charge, for giving the heat required in coking. Of these,



FIG. 4.—GENERAL VIEW OF MESSRS. APPERT BROS.' GLASS WORKS.

or with his foot through the intermedium of levers, so as to produce the expansion that he requires.

The first apparatus is the ordinary glass-blower's chair. (Fig. 1), which we allow its full dimensions. The second, which is called a "swan's neck" (Fig. 2), serves for moulding with the stationary or revolving mould. The third is used for blowing in the air such articles as balls, mattresses, etc. (Fig. 3). All these apparatus are movable, and are adapted to the coupling screws of the lower piping of which we have spoken. For the blowing of glass that is to be rolled a leather pipe is applied to the blowing tube by the boy who helps the workman; such is the case in the manufacture of tubes and of cylinders for window glass. In this case the compressed air is distributed by an inclined plane at the end of the hall, over which descend the distributing pipes.

Results of the Use of Compressed Air.—The advantages derived from the use of a compressed air are of several natures: It permits us, in the manufacture of drinking glasses, to entirely do away with blowing by the mouths of children, and, with very rare exceptions (mostly through inattention of the workman), with blowing by the mouths of adults.

It protects these latter, then, against the special affections that were brought on by the old method of blowing. There being less fatigue for the workman, he produces better work, and a greater quantity of it, and the articles are manufactured with greater precision. Finally, the use of our process permits of obtaining, without fatigue of our men, articles of dimensions that have been hitherto unknown, both as regards bulk and other dimensions, such as length and thickness. The limits that may be reached are governed only by the weight of the material operated upon. This process, moreover, is very elastic, since, in consequence of the successive expansions that the workman produces at will, the pressure may ascend from 5 to 3,000 grammes per

cumstances as to prevent the utilization of the volatile products in any way whatever; moreover, that these valuable articles of commerce are blackening and defacing the surface of the country. In some cases, it is true, the fumes have been collected, and passed under a boiler for generating steam, the products of combustion escaping from a high chimney; and, recently, close distillation has been successfully carried out in the ovens of Mons. Carves; but I am certainly within the mark when I say that the gaseous products of nearly the whole of the 20,000,000 tons of coal annually coked in this country are absolutely wasted, and set free to injure vegetation. A fair idea of the meaning of such a statement may be gathered by considering the loss from this cause actually taking place in one of our greatest industries, that of pig iron. From published returns, it appears that last year there were 575 furnaces in blast in the United Kingdom, producing 8,450,000 tons of pig iron. In the majority of these furnaces the fuel is coke; but in a considerable number raw coal is still used, and of these, in only two cases, the volatile products are condensed, and recovered by a process introduced by Mr. Ferrie, though I believe the system is now being extended to fourteen other furnaces. With this exception, and neglecting the few ovens on the Carves and on the Jameson systems at present in operation, we may take it that the condensable volatile products of all coal used in the manufacture of pig iron are entirely lost, while, in those cases where the coal has been previously coked, much of the gas is wasted likewise. Deducting, therefore, the 36,500 tons made in the two Ferrie furnaces from the total production, and taking an average of 34 cwt. of coal per ton of pig iron, we find that for this one industry alone as much as 14,302,000 tons of coal are being thus wastefully dealt with, representing, for oil

so far as I am aware, externally heated ovens have alone been successful in practice.

Now, without entering into any detailed criticism of this system, which doubtless gives good results, I must just mention what appear to me to be its principal objections, in order that I may the more easily show in what respects Mr. Jameson's plan is, in my opinion, to be preferred for the treatment of large quantities of coal.

A great objection to externally fired ovens is their excessive first cost, and, on account of their special form, it is quite impossible to alter existing plant for the carrying on of the process; then again, there is a considerable waste of heat, owing to the high temperature which must be maintained within the flues, a consideration which will, perhaps, be best appreciated by remembering that in ordinary gas works, with externally heated retorts, about twenty-six per cent. of the total coke produced is consumed for heating purposes; and finally, there is the cost of repairs, which cannot fail to be greater than usual, on account of the number of flues, all exposed to intense heat, and the practical difficulty of having to quench the coke after withdrawal, a proceeding which, as is well known, is apt to leave an excessive amount of water in it when sent out to the purchaser. Added to this, the beehive oven is that which is generally acknowledged to be not only the easiest built and kept in order, but also to produce the highest quality of coke. At the same time, it cannot but be admitted that, in certain cases, where no use could be made of the gas, it might be more economical to dispose of it for heating the charge rather than let it go to waste; but this, I need scarcely point out, should be a very exceptional circumstance, and one which could hardly exist at all in this country, if the value of gas, as a heating agent, was more fully recognized.

In applying Mr. Jameson's process, it is not necessary to

* A paper lately read before the Society of Arts, London.

rebuild the ovens, the form being retained precisely as in use at the present time, and the extraction of the gases accomplished either by inserting in the floor a couple of perforated iron pipes connected with an exhaustor, or, preferably, by forming the bottom with perforations in the fire-clay quails themselves, and applying a slight suction through all the openings. The process is, therefore, immediately applicable to the whole of the ovens treating the 20,000,000 tons of coal annually coked, and if this were done, there would be obtained from this source alone ammonia corresponding to at least 90,000 tons of sulphate, at present worth more than £1,250,000. The oil would also be worth some £2,000,000, and the gas, at even 3d. a thousand cubic feet, would come to £2,500,000, making in all the enormous total of £5,750,000 as the commercial value of products now being entirely wasted in the coking process.

The diagrams show an ordinary beehive oven adapted to the recovery process. The only alteration is in the floor, which, with the exception of the solid margin, consists of perforated fire-clay quails laid on a bed in which are formed the passages, these passages communicating with the main pipe by means of the branch, in which is an ordinary screw-down valve or water-lute connection for shutting off the oven when not in operation. The object of the arrangement is to draw off the gases at the bottom by producing a slight suction in the main pipe. It is, therefore, important to have a secure and tight foundation, so as to avoid drawing in air and vapor from the surrounding ground, and for this end it is well to have a double layer of bricks set in hard pitch, at such a distance down as not to be exposed to undue heat, as well as to have a good damp-proof course, such as is laid in the foundations of a dwelling-house.

A bench of twenty ovens with recovery plant is also shown. The main pipe, with which each oven is connected, extends along the entire length underground, with a fall toward the condenser, which, in its simplest form, is a range of cast-iron pipes exposed to the cooling action of the atmosphere, or surrounded by water in cases where it can be obtained without much expense. The condenser discharges through a lute into the separator, a pipe being carried on to the exhaustor or fan, driven by the engine, the speed of which can be regulated to obtain the proper suction required at the different periods of the operation. From the exhaustor, the gases, deprived of their condensable constituents, may be taken where desired, but the diagram shows them discharged under the boiler for generating the steam required by the engine. The liquors, being delivered into the separator, arrange themselves according to their specific gravities, and a rough division is therefore made by running off the crude oil into one tank, and the ammoniacal liquor into another.

The cost of altering existing ovens to Mr. Jameson's plan is stated to be from £15 to £20 each, this sum including all requisite connections and condensing-pipes, which are of the simplest possible description. Bearing this in mind, as well as the fact that the increased cost of working the new system does not amount to one penny per ton of coal, it will be seen that not only is there no impediment, on the score of outlay, to prevent the immediate adoption of the process, but that the sale of recovered products is likely to become an exceedingly profitable undertaking.

The action is as follows: The ovens are charged from the top, and in the usual manner ignited. A suction equal to about one inch of water is then applied by the exhaustor through the pipes to the bottom of the charge, and the products of distillation continuously drawn off, the charge, to all appearance, burning in the usual way. During the process, the effect is produced of a gradually increasing heat, commencing at the top, and passing downward slowly to the temperature of intense incandescence in every part of the oven. In the old system, the gases and vapors, evolved at a comparatively low temperature percolate through the more highly heated upper layers, and there suffer decomposition; but in Mr. Jameson's process, while the operation of coking is, to all intents, going on in the ordinary way, the gases and vapors are withdrawn as they form and any decomposition effectually prevented. In point of fact, from the moment of formation they are actually cooled, heat being abstracted by the unchanged portion of the charge toward the bottom of the oven, this being shown by the circumstance that, when taking away about 200 cubic feet of gas per hour per ton of coal, and continuing this withdrawal for about sixty hours, the temperature of the pipe, on emerging from the ground, does not average more than 180° Fahr.

Owing to the supply of air being admitted at the top, the upper surface of the charge suffers combustion, so supplying most of the heat requisite for coking. The advantage of thus utilizing a portion of the highly heated coal charge itself, is twofold. In the first place, by using carbon as the heating agent, a thermal intensity is gained which cannot possibly be reached by the combustion of the gas, while, in the second place, the average quality of the coke is improved. All those acquainted with the making of coke in the ordinary way will be aware that the top layer is extremely porous and inferior, from being formed at a low heat, in a comparatively cool freshly charged oven. It is this upper surface that is burnt off in the Jameson process, and so an objectionable element is got rid of.

From what has been said, it will be seen that the production of coke in the Jameson ovens must necessarily be somewhat less than with close distillation. This difference amounts to not more than 2 cwt. of coke per ton of coal treated, in favor of externally heated ovens. On the other hand, however, it is claimed for Jameson's process that the average quality of coke is better, and of course, as a set off against the lessened production, there is the saving in valuable gas, which may be used for heating, for giving power, or for lighting in connection with such burners as the Lewis or Clamond, which depend for their illuminating power on the incandescence of platinum or some other incombustible material, instead of on the fine particles of carbon deposited in the flame itself. There are also advantages for the Jameson system on account of lessened first cost, and its adaptability to ovens now in existence. These are most important factors, and though it is impossible to place any average money value upon them, they must not be overlooked when considering the merits of the new process.

The volatile products are the products of distillation of coal at a low temperature, and are to be regarded as the vapors of various hydrocarbons of the paraffin series and of ammonia saturating an atmosphere consisting chiefly of hydrogen, nitrogen, and carbonic oxide. Up to the present time, with the imperfect condensing apparatus employed, the data indicate that an average yield of about eight gallons of crude oil, and ammonia equal to a production of ten pounds of sulphate, may be expected per ton of coal; but with improved condensing arrangements, there is no doubt

that a considerable quantity of vapors, especially ammonia, now lost, will be recovered. The oil is a crude paraffin of specific gravity about 0.96, and contains a considerable quantity of solid paraffin of high melting point; but both quality and quantity vary so much with the kind of coal under treatment that on this point it is impossible to give more than a general idea. The following table gives a few of the results obtained per ton of coal treated:

Kind of coal.	Gals. of crude oil.	Ammonia estimated in pounds of sulphate.
Shiremoor.....	13	9.87
Brancepeth cannel.....	12.2	6.00
Longhirst, small.....	9.28	17.78

The following may be taken as an average analysis of the crude oil:

	Per cent.
Lubricating oil.....	39.5
Burning oil.....	37.7
Paraffin scale.....	13.5
Tar and loss.....	9.3
	100.0

In reference to the question of condensation I should like to draw attention to a process which, though successfully tried on a practical scale some years ago, has, to my mind, not yet received the attention it deserves. I refer to the compression of the gas and vapor, and the subsequent cooling of them when under compression; first, by an external application of water, and then of the gas itself, cooled much below its original temperature by expansion behind a piston after its passage through the condenser under compression. This method formed the subject of an interesting paper, read before the Chemical Society of London, in 1873, by Mr. J. J. Coleman. It will be easily understood by remembering that, under constant temperature, an increase in pressure decreases the capacity of a given weight of gas for holding vapor in solution. In a saturated mixture, therefore, a vapor will be condensed and deposited, either by an increase in pressure or a reduction in temperature. The process referred to accomplishes both, and by its means the volatile products, after being treated by all ordinary condensing apparatus, may be made to yield liquors of low specific gravities and boiling points which might be valuable as local anesthetics, or as the refrigerating media in ice-making machinery.

Reference should be made to the method of fractioning, for the purpose of getting an automatic separation of the products, according to the temperatures of liquefaction, without future distillation. This is now being carried on at Felling by Messrs. H. L. Pattinson & Co., who, by placing discharge lutes at five different points in the condensing pipes, are obtaining liquors of specific gravities from 0.945 to 1.015. Another mode of separation is one by which a series of five gas mains is provided, and connections made so that the gas may be passed into each main in turn, for the purpose of securing some difference in the quality as well as a fractional separation of the by-products. With this arrangement, the discharge of gas is, every twelve hours, or at other convenient interval, passed into a different pipe for separate condensation, all the freshly charged ovens delivering into the first pipe, and so on through the series, according to the time which has elapsed since the commencement of distillation. Suction being applied through the last main during quenching, the pipes would be cleared of coherent dust and oil, and a considerable quantity of carbonic oxide and hydrogen obtained, as well as ammonia, which would otherwise have been wasted in the quenching water.

Mr. Jameson's process is in operation at the Felling works of Messrs. Hugh L. Pattinson & Co., and at the Page Bank Colliery of Messrs. Bell Bros. & Limited, and is at the same time being introduced in the works of the Weardale Iron Co., and at some collieries in Northumberland. A number of experiments have been carried out by Mr. Lowthian Bell, F.R.S., to test the value of the system, both in regard to the yield and quality of coke, and the value of the recovered products, and further investigations are now in progress, as well as extension of the plant, so as to obtain sufficient coke for the entire working of a blast furnace.

An interesting application of an analogous patent, recently taken out by Mr. H. L. Armour, and the property of the Jameson Coke Company, Limited, has just been made in the case of a pit heap, at Seaton Burn Colliery, in Northumberland. A pit heap is a deposit for quantities of small coal and dust for which, as a rule, no market can be found, as well as for shale and iron pyrites met with in working the coal. These heaps are generally burning, and, in very many instances, give off so much smoke and dirt as to become a terrible nuisance to the neighborhood. This was the case at Seaton Burn; but by simply covering the heap with sand, and sinking a number of iron pipes connected to a main, in which a constant suction is maintained, all offense has been removed, and a stream of gas, yielding both oil and ammonia, is obtained. In this manner a worse than valueless property has been converted into a profitable one, and as the system is now being extended to large heaps at Kelvin-side, near Glasgow, it is to be hoped that before long an end will be put to one of the greatest nuisances in colliery districts.

Though many of the members of this society are far better acquainted with the commercial value of the recovered products than I am, I must now ask you to let me say a few words as to the probability of such large quantities of oil, ammonia, and gas being profitably employed in the various industries which do exist and are likely to exist in this and other manufacturing countries.

At the present time, we depend for our supply of petroleum or mineral oil on two principal sources—the natural springs of Canada and the United States, and the distillation of bituminous shale, which has been developed in Scotland into an immense industry chiefly by the instrumentality of the late Mr. James Young. According to statistics published in *The Oil Trade Review*, it appears that in 1882 we imported from America 41,500,000 gallons of petroleum oil, and close on 6,000,000 gallons of petroleum spirit or benzoline. Toward the end of the year, the price of the oil, which for the first nine months had ruled about 5½d. a gallon, received a sudden rise, owing to reports reaching this country of the failure of the supply, and went up to as much as 7½d. and 7¾d. a gallon. Without, however, attaching too much importance to the apparently failing supply of American oils in estimating the value of the English product, there can be no doubt that, at the present time, the average daily supply is nearer the daily consumption than it has been for the last five years, and it is in the highest degree probable that a permanent rise in price will before long be made, unless supplies come in from other sources. Some

interesting particulars respecting the petroleum supply were given in the Society's *Journal* for September 1, 1882. With regard to the distillation of shale, few persons are aware of the immense magnitude of the works engaged in this industry. Altogether, in Scotland, there are about seventy oil works, at about forty of which crude oil alone is made; and I find, from particulars supplied by Mr. Thos. Scott, of Edinburgh, that there are two companies, each distilling 700 tons of shale per day, while two others each distill 400 tons, and five others, each 200 tons. Two firms each make 12 tons of paraffin candles per day. When it is remembered that something like 30 gallons of crude oil and ammonia, equal to 17 pounds of sulphate, are obtained per ton of shale, the importance of the industry and the great demand for the products will be apparent. Shale oil works also exist in Wales and Cheshire, but are now almost kept going in refining crude oil from Scotland on account of their supply of shale being exhausted. The great demand for crude oil is for the manufacture of illuminating and lubricating oils and solid paraffin, while from some are obtained the aniline dyes and other valuable products.

Illuminating gas of a very high quality is also made from the oil, and recently this application has received considerable development by Messrs. Rogers Brothers, of Watford, who have succeeded in producing an oil gas of great brilliancy and purity, which promises to compete commercially with gas made from coal in the ordinary way. The "Koh-i-noor" gas, as it is called, is made by injecting a continuous stream of oil into the end of a small iron retort by means of a jet of highly superheated steam. After flowing to the end of this retort, the stream returns through an annular space formed by a second tube placed outside the first, and externally heated by a coke fire. The gas is then conducted to a small washer, and requires no purification, as it contains neither sulphuretted hydrogen, tar, nor ammonia. Its cost is stated to be about two-thirds that of coal gas for equal light, 300 cubic feet of 70-candle gas being produced from two gallons of oil; and a great advantage of the process is, that any existing gas works can be converted at a comparatively trifling cost, while, on account of the high illuminating power, a main of given size can transmit more than four times the amount of light that it does at present.

With regard to ammonia, it will be known to most of you that there has been rapidly springing up of late years a new process for the manufacture of soda, perfected by M. Solvay, of Brussels, and known as the ammonia process. In a recent paper, read before the Society of Chemical Industry of London, by Mr. Walter Weldon, F.R.S., it was pointed out that, though the commercial success of M. Solvay's process only dates from 1866, yet already 163,000 tons a year, or 23 per cent. of the total soda production of the world, is made by it, and that at the present time seven large works, capable of making about 7,000 tons of ammonia soda per year, are being built, while several others are in contemplation. In point of fact, the Leblanc process threatens to become extinct, unless some means are discovered for greatly lessening the cost of production. Now, notwithstanding all that can be done, the annual loss of ammonium sulphate in making the 163,000 tons of soda amounts to no less than 9,000 tons, so that, in this trade alone, it is evident that the demand for ammonia is likely to be very great and increasing. Curiously enough, in the same paper, Mr. Weldon not only pointed out that the Jameson process would be likely to supply the demand for ammonia created by the extension of M. Solvay's system, but that by its means it might be possible to so lower the cost of production of Leblanc soda as to enable it to successfully compete with that made with ammonia. In the Leblanc system, fuel, which at the present time is coal, amounts to as much as 350 per cent. on the weight of soda produced, while M. Solvay uses but 150 per cent. It was, therefore, suggested that the Leblanc soda makers should entirely cease to use raw coal as a fuel, and should convert all their coal, except that used for mixing in the black ash process, into coke, collecting for sale the oil and ammonia, and utilizing the gas for heating purposes. If this could be done, and duff, or very small coal, used for coking, the soda maker would virtually obtain his fuel for nothing, as the value of the recovered products would cover the original cost of the coal, and, in some cases, the expense of coking as well.

Turning to agriculture, it is evident that now that the guano deposits are becoming exhausted and poor in quality, the demand for artificially produced manures will increase year by year. In a letter from Dr. Angus Smith, read at a meeting of this Society on the 26th of January, 1881, it was stated in effect that the ammonia from 1,000,000 tons of coal, if used in manure as ammonium sulphate, would add about £53,400 worth of food to the produce of the land; while, if the ammonia from all the raw coal now burnt in this country was utilized in agriculture, we should add £50,000,000 worth of bread stuffs, and might begin to export. Without venturing to say that this could be realized, I think it will be agreed that an increased supply of ammonia must be of immense importance to the agricultural prospects of this country.

The great value of ammonia renders it imperative that the greatest possible production should be obtained. It is usual to say that coal contains so much ammonia, but it is of course well known among chemists that such a statement is untrue, only the elements for its production being contained. These are nitrogen and hydrogen, and as the latter gas is always present in much greater quantity than is needed for the conversion of all the nitrogen into ammonia, it is the amount of nitrogen present that should determine the ammonia-producing power of any coal. Unfortunately, only a small proportion of the nitrogen is thus made use of, about 40 per cent. remaining in the coke unchanged, while a large percentage is driven off with the gas in its elementary condition, and only from 14 to 20 per cent. combines with hydrogen to form ammonia. There is, therefore, much scope for ingenuity in finding some means for further utilizing the supply of nitrogen, and it is to be hoped that the researches of Professor W. Forster, M.A., some of which were embodied in a paper read before the Chemical Society of London, on the 21st of last December, will throw greater light on this important subject.

The composition of the gas collected from the Jameson ovens, after its passage through the condenser, varies according to the coal under treatment, and the length of time the charge has been burning. An approximate average is given in the following table:

CO ₂	3.5
CO.....	27.5
H.....	29.3
O.....	1.1
N.....	38.6

100.0

And from this it will be seen that, compared with London coal gas of average quality, its calorific power is about one-third. As a heating agent, therefore, assuming its cost to be 6d. a thousand cubic feet, the price for a given effect will be 1s. 6d., as against, say, 3s. for ordinary coal gas.

It cannot be overlooked that there is a very widespread feeling that the time is not far distant when the existing method of obtaining motive power by the generation of steam will be superseded by a more economical process, in which heat energy will be directly converted into mechanical work, without the intervention of a fluid such as steam, which, in the best compound engines, only permits a utilization of about one-tenth of the energy developed in the furnace. Expression was given to this by Sir Frederick Bramwell, F.R.S., at a meeting of the British Association in 1880, when he stated that if the Mechanical Section of that association should meet fifty years hence, he thought members would not speak of the steam-engine except as a curiosity to be found in museums. At the present time, gas engines of comparatively small power, constructed by Crossley Brothers, Limited, and using Dowson's gas, are actually working with a fuel expenditure of 1.4 lb. per indicated horsepower per hour, a performance rather better than that of the best steam engines; and though there are, doubtless, many practical difficulties to be overcome, I certainly look forward to the time when our present wasteful method of using coal, for obtaining motive power, will give way to a system more in accordance with the spirit of the age.

With these considerations in view, I think it is certain that the gas recovered in the coking process, instead of being consumed under a boiler, will be utilized in gas engines, for the production of all power required in the neighborhood of the ovens, for the working of the colliery and other machinery, and in adjacent factories; while there is also the probability of its use for the generation of power in the form of electric energy, to be transmitted for conversion into light or mechanical work. In this latter case, I of course refer to the establishment of large generating centers in the immediate neighborhood where the gas is produced, and in this connection the recent experiments of Deprez and Herz are especially interesting, and may possibly give the proposed application still greater importance.

It now only remains for me to ask your attention for a short time, while I make an appeal in favor of the substitution of gas and coke for heating purposes, both in manufactories and dwelling-houses, where raw coal is now employed. Look at it how we may, the use of raw fuel at the present time is only to be regarded as a relic of former ignorance, handed down for a time when the chemical compositions of coal and its products were unknown, when there was no use for ammonia, or for what we now call the by-products, and when economy was the last thing thought of, provided the desired result was obtained. Now, however, all this is changed. We have ascertained the composition of coal and its products with the greatest accuracy, and we know, as an absolute fact, that in burning the condensable volatile constituents we are consuming materials which, if applied in the arts and manufactures, have an intrinsic value many times above what they bear as heating agents. Besides which, we are producing smoke and dirt, fouling the atmosphere, and encouraging certain forms of disease, and in domestic fire-places, according to a favorable estimate, are sending 60 per cent. of the heat up our chimneys. And what is the set-off against all this? Nothing at all, as far as I can see, in regard to manufactories, where it is admitted gas would be a cheaper, more convenient, more easily regulated, and more cleanly fuel; while, in domestic fire-places, the luxury of having a blazing fire which can be poked is the only reason I have heard alleged in favor of the retention of the present system, which involves more expense and more labor than if gaseous fuel or coke had to be dealt with. I am not now alluding to the use of ordinary illuminating gas, which Sir Wm. Siemens has shown can be economically and advantageously applied as fuel in combination with coke; but I refer to a gas made specially with a view to heating purposes, such as the gas obtained in the Jameson process, and which would be supplied at a cost of not more than 6d. a 1,000 cubic feet. Such a gas would be available for all manufacturing purposes, and by using it with some regenerative system, the highest economy would be attained. It would also be delivered to our houses, and consumed for cooking and warming, either with or without coke, while it would also be suitable for driving gas motors, if indeed electricity, generated by engines worked with the gas near its point of production, had not previously stepped in for driving our domestic machinery. It is, however, difficult to see how electricity could compete with gas as an economical motor, unless it was on the score of simplicity, as with gas at hand, except under special conditions, it would obviously be cheaper to use it directly in an engine than through the medium of electric energy.

An interesting paper by Mr. George E. Davis is published in the February number of the *Journal of Chemical Industry* from which much practical information can be obtained as to the comparative values of various methods of warming rooms. The results arrived at, after many carefully conducted experiments, were that one ton of dry coke, burnt alone in a suitable stove, has the same heating effect as a ton of Lancashire coal, and is smokeless, and that twelve cubic feet of ordinary coal gas is about equal in heating effect to one pound of coal. In the following tables are given summary of costs for coal, coke, and gas, the latter being of the usual quality supplied in Manchester and rather better than what we have in London:

		Pence.
In fire-	{ Coal, 40 lb., at 8d. a cwt.....	2.86
grate. ..	{ Coke, 50 lb., at 7s. 6d. a ton.....	2.00
Gas-stoves	{ Fletcher's, 240 c. ft., at 3s. per 1,000 ..	8.64
	{ Lux Calor, 200 c. ft., ..	7.20
Stove.	{ Coal, 18 lb., at 8d. per cwt.	1.20
	{ Coke, 20 lb., at 7s. 6d. a ton.	0.90
In a stove in use in Mr. Davis' study the cost per day is—		
Coke for 13 hours, 14 lb., at 7s. 6d. a ton.....		0.56
Gas for lighting, 10 c. ft., at 3s. per 1,000.....		0.37
Total.....		0.92

and the temperature of the room is raised from 45° F. to 60° F. in one hour, and easily maintained. It would, therefore, seem that as a heating agent, coke is by far the most economical, especially when applied in a close stove. Unfortunately, however, this mode of application is one which is open to objection from several points of view. It first of all is incompatible with the generally accepted idea that the fire must be visible, and then there is the chance that, through some negligence, carbonic oxide may be permitted to escape into the room. I am, therefore, inclined to think that we

should look to the heating of our dwelling-houses by the combustion of coke, with or without gas, in an open fire-place, specially constructed to carry on the operation in an economical way, but for convenience in lighting the coke, and in regulating the temperature, as well as from the more pleasant appearance of the fire, it appears probable that the combination of coke and gas, as suggested by Sir W. Siemens, will be the method more generally adopted.

At the present time, it is estimated that about 80,000,000 tons of coal are annually consumed in the raw state in this country. Probably part of this coal is unfit for coking; but even taking 60,000,000 tons as the quantity which might be treated by the Jameson process, we have, at present prices, £17,250,000 as the annual value of the by-products now being wasted, provided the gas could be utilized in the manner previously mentioned. This is exclusive of the sum of £5,750,000, previously referred to as the value of products which might be recovered from coke ovens now in operation, which would bring the total to no less than £23,000,000 a year. Besides this, it is possible to bring into use large quantities of duff and shale now left at the pits, from which both oil, ammonia, and gas could be extracted. The attainment of such a result is of immense importance, but it can only be accomplished along with the introduction of improved systems of obtaining motive power and heat, and surely these are matters well worthy the serious consideration of the members of this Society.

I will not now detain you further, but will conclude, in the hope that what I have had the honor to lay before you this evening has been sufficient to establish the following propositions, which I had in my mind when I commenced:

1st. That Mr. Jameson's process meets a great industrial want that has hitherto not been met.

2d. That it is desirable to do away with the use of raw coal as a fuel, substituting for it coke and gas, after the separation and recovery of the more volatile constituents.

MARIANINI'S RE-ELECTROMETER.

AND ITS USE IN THE STUDY OF ATMOSPHERIC ELECTRICITY.

In his lecture upon lightning rods, some time ago, Mr. Melsens mentioned the use of Marianini's re-electrometer for the study of atmospheric currents. This apparatus, which is a very old one, is not generally found described in

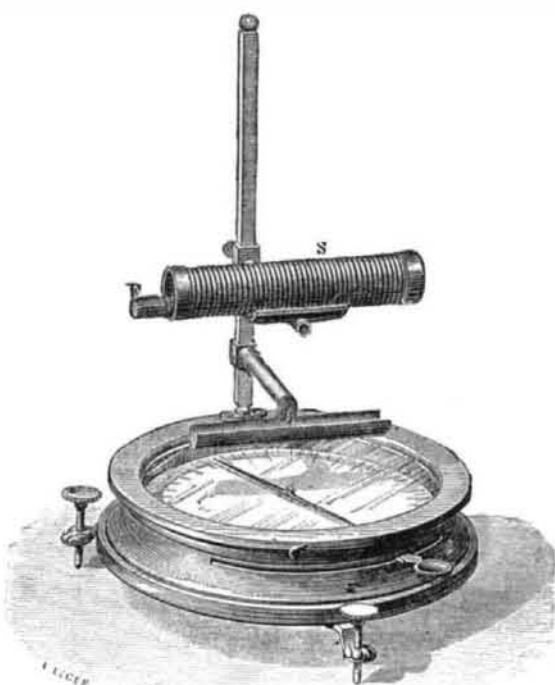


FIG. 1.—MARIANINI'S RE-ELECTROMETER.

treatises on physics, and, as the mention of it in Mr. Melsens's note has brought us some inquiries in regard to it on the part of our subscribers, we have thought we could not answer them better than by devoting a few lines to the apparatus in this place.

The instrument was invented by Mr. Marianini in 1833 in order to serve as a galvanometer in some researches on the currents produced by piles. He had had the idea, in order to measure the intensity of currents, of availing himself of the magnetization that they produced in iron, and of measuring such magnetization by the deviations brought about in a magnetic needle by the polarity acquired by the metal.

His first apparatus consisted of a soft iron cylinder, 2 millimeters in diameter and 7 centimeters in length, covered with silk, and upon which was wound a silvered copper wire helix, one-fifth of a millimeter in diameter, and likewise covered with silk. The electro-magnet thus formed was placed above the center of an ordinary compass. The axis of the iron cylinder was at right angles with the magnetic needle, and the centers of this latter and of the electro-magnet, placed in the same vertical, were about 15 millimeters distant from one another. When a passage of a current into the helix had magnetized the iron of the cylinder, the needle deviated to the left or the right, according to the direction of the current, and such deviation was taken as the measure of the current's intensity.

After having used this apparatus with continuous currents, Marianini discovered that it was perfectly adapted for the study of instantaneous ones, such as those that are produced in the discharge of a condenser. In fact, upon discharging a Leyden jar through the helix, the iron was magnetized, and a deviation of the needle was obtained. But, as the iron preserved a certain amount of remanent magnetism, it became necessary, after each experiment, to bring it back to a neutral state through weak contrary discharges. In order to permit of this operation being performed by heat, or, if need be, to replace the iron bar, Marianini, instead of winding the wire directly upon the bar, wound it upon a glass tube into which there could be placed different bars when desired. Besides this, in order to vary the sensitivity of the instrument, he furnished the helix with a movable support, by means of which it could be placed at different distances from the needle.

The apparatus thus modified is shown in Fig. 1, from the type which was exhibited in the Italian section of the Ex-

hibition of 1881. The compass was, as may be seen, supported by three leveling screws, and its cardboard dial was capable, by means of an external appendage passing through a groove, of being moved within certain limits, so that its zero might be made to coincide perfectly with the position of the needle. From the edge of the box rose a vertical rod upon which ran one or more slides that carried grooved holders, L, upon which could be placed one or more helices, S, containing iron bars, F.

Another type, which was designed for the most delicate researches, had its needle suspended from the thread of a cocoon. Its general aspect was that of a Nobili galvanometer with very high supports. The rod carrying the slide was below the compass, and the helix was beneath the dial.

With this apparatus Marianini made a certain number of interesting researches.* He discovered, in the first place, certain analogies between instantaneous electric currents and voltaic ones, and then he demonstrated, in 1837, the induction produced by instantaneous currents, and which he named "leyden-electric."

In 1840 he ascertained the curious fact that a bar of iron magnetized several times in one direction by instantaneous discharges, and then brought back to a neutral state by reverse discharges, acquires a greater aptness for being magnetized in this same direction, and a less one for undergoing a contrary magnetization. In 1843 he made known the use of the re-electrometer "as a means of discovering the direction of lightning."

"I have," said he, "demonstrated that, by means of the re-electrometer, we may turn aside from an excellent metallic conductor a portion of the ordinary electric current that is traversing it. I believe that we might be able to obtain the same result by acting upon the atmospheric electricity of lightning. To this end, I would propose to put in communication, by means of two long wires, the two extremities of the helix of the re-electrometer with two not too close points of an ordinary lightning-rod. I would place in the glass tube of the re-electrometer a bundle of iron wires, and, underneath, a compass so arranged that the axis should make a right angle with the magnetized needle, and that the middle of this axis and the center of the needle should be in the same vertical. Thus, every time that the lightning traversed the rod, a small portion of the electricity would circulate around iron wires, and the deviation of the needle placed beneath would indicate the deviation in magnetization, that is to say, would make known whether the lightning had ascended or descended the rod.

"Such an indication would be surer than that deduced from the electric state of the atmosphere before the appearance of the lightning, for it often happens in storms that the electric state of the atmosphere passes rapidly from positive to negative, and *vice versa*. However it is not stated

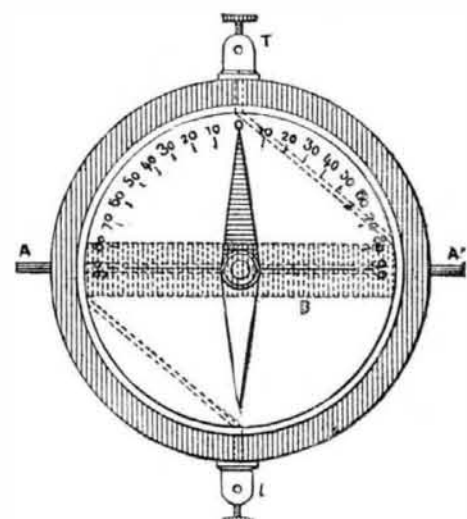


FIG. 2.—MELSENS'S MODIFICATION OF THE APPARATUS.

that from such an electric state of the atmosphere we can with certainty deduce that of the storm-cloud. Besides, the indication given by my instrument would have the advantage that it could be observed without haste, since the magnetization produced by instantaneous currents does not disappear, at least in great part, with the same rapidity as that derived from voltaic currents.

"Although the fraction of electricity turned aside from the conductor might be rendered as small as desired, and that too by having very near each other on the lightning rod the two starting points of the wires that communicate with the helix, yet there might be reason to fear that such small fraction would melt the wire that it was traversing.

"In order to overcome this difficulty, the instrument might be used in another way, that is to say, the two extremities of the re-electrometer helix might be made to communicate by means of a wire, so as to constitute a closed circuit—about a meter of this wire being in a direction parallel with the lightning-rod, and a few meters distant from it. I am convinced, from my own experiments on the spark of the electric machine, that the re-electrometer would show the passage of the lightning in the rod; and, in this case, the instrument being electrified by induction, its indications would evidently be in a direction contrary to those that it would have given had the wire been traversed by a portion of direct electricity. It is very true, as we have seen, that when instantaneous currents act through induction, they produce a magnetization, now in one direction and now in another; but I have already remarked, in preceding memoirs, that when the tension is great the induced current has always the same direction, and that if the iron is entirely devoid of magnetization it will always become magnetized in the same direction.

"It is possible that, by this method, and only in increasing the length of that part of the wire that is parallel with the lightning-rod, the re-electrometer may be able to signalize the striking of lightning at notable distances; for, if a small Leyden jar gives us inductions at a distance of 80 centimeters, may we not conclude therefrom that lightning will give them at a distance of several meters? I would even dare hope that magnetization through induction might be obtained when the lightning was merely playing between the clouds, since leyden-electric inductions occur even when

* See *Annales de Chimie et de Physique*, 3d series, vol. x., p. 491; vol. xiii., p. 245; and vol. xvi., pp. 436 and 448.