he used it entirely for springs and also with advantage for tyres. He likewise found it an excellent material for tool steel.

Mr. Winder next read his paper on the failure of chilled rolls. The breakage of rolls is one of the most annoying of the many troubles with which the producer of manufactured iron has to contend. This is a matter which has hitherto received too little attention, it being generally considered to be in the nature of rolls to break, and nothing man could do would prevent it. It is as evident as like produces like, that if some rolls will last for considerable periods of time, others of exactly similar description, and working under the same conditions, would stand equally long. Sometimes four or five rolls—the author instances eleven in a fortnight—will give out one after another, until at last one will be found to accomplish the work. Mr. Winder, as a roll founder, endeavours to bring some sort of order into the process of manufacture. He points out that when a train of rolls is hard at work in the present day they will turn out as much as 1000 tons a week, and the passing of this great weight of red- and white-hot billets or blooms will be almost equal to putting the rolls into a furnace. The necks of the rolls are, however, kept cool by water, so that the lubricant may not be burnt off, and the sudden cooling thus caused produces a molecular change in the metal which, the author considers, accounts for much of the mischief. In order to overcome this difficulty it is recommended that there should not be too sudden a reduction of the diameter of the body of the roll where the neck is formed. That, in brief, appears to be the author's opinion, and doubtless his advice is good; in fact, it follows one of the cardinal laws observed by good iron-founders in the casting of other articles besides rolls. A good practical discussion followed the reading of the paper. We think that foundry practice is a little behind in this country, and in this respect we might, with advantage, take a hint or two from American methods, perhaps more especially in regard to smaller castings than chilled rolls, which often fail unaccountably in the United States also. The advice to roll founders to cast with a bigger head should not be, but apparently is, necessary. Prof. Turner's remarks were to the point, and it would be of advantage if he would make his researches in this direction more fully public.

Prof. H. S. Hele-Shaw was the author of the last paper read on the Wednesday of the meeting. The Walker Laboratories form part of University College, Liverpool, and are among the most recent and best arranged establishments of the kind. They have been erected under the guidance of the author of the paper, who occupied the chair of Engineering Science when the school was in a far less magnificent form. We have not space to follow the author in his description of the buildings, or the method of instruction. The latter appears to be framed in a manner calculated to turn out good engineers, a class which cannot be too large for the welfare of the country, although complaints are growing daily that they are already too numerous for their own advantage.

The last day of the meeting was Thursday, September 22, when two papers were read. The first was the contribution of Mr. Saniter, and in it he described the process by which he proposes to remove sulphur from iron by calcium chloride and lime. The experiments quoted go to prove that lime alone removes a considerable quantity of sulphur from iron if the contact is sufficiently prolonged; and, further, that a mixture of calcium chloride and lime completely eliminated the sulphur in the space of half-an-hour. Chloride of calcium is a by-product of the manufacture of ammonia, of soda (by the ammonia process), and of Weldon's bleaching process. The author states that the production amounts to many thousands of tons, of which only ten per cent. finds useful employment, the remainder running to waste. The subject is one of considerable importance, and no doubt the process will be freely criticized when it comes up again for discussion at the next spring meeting.

Mr. J. E. Stead's paper on the same subject—the elimination of sulphur from iron—was a much more imposing contribution, covering 40 pages of the proceedings. It dealt broadly with the whole question, and forms a most valuable contribution to the literature of the subject. At the conclusion of the reading of his paper Mr. Stead said that since it had been written he had had further light thrown on the matter by experiment and otherwise. He therefore proceeded to read from a MS. certain fresh matter, which appeared to occupy as much space as the paper itself. No doubt Mr. Stead will weld the original paper and the additions into one harmonious whole, which will then form a standard work of reference on a subject which has come to the fore so much within the last year or two. We congratulate Mr. Stead upon his courage in dealing with this matter in the way he has, and especially upon the practical disclaimer of infallibility which the appendix to his paper supplied.

There was no discussion of these papers, their consideration being adjourned until the spring meeting of next year. The matter should be well thrashed out, as speakers will have had an opportunity of consulting authorities, marshalling facts, or even making fresh experiments. It is to be hoped that in the future more discussions will be arranged on similar lines.

The proceedings closed with the usual votes of thanks to those in Liverpool to whom the Institute was so largely indebted for the success of the meeting.

There were several excursions during the week. The chief of these were to the Manchester Ship Canal, the Vyrnwy Water Works, the Lancashire and Yorkshire engineering shops at Horwich, the Liverpool Overhead Railway, and Laird's shipyard. A visit was also paid to the Walker engineering laboratories, where Prof. Hele-Shaw had collected some very interesting models for the occasion. The most striking of these was an exceedingly intelligent chain-making machine which has recently come over to this country from the United States. The whole of the operations are automatic, reels of wire going in at one end of the apparatus, and coming out one continuous length of chain at the other, and this without human intervention of any kind. The machine may, in the ingenuity of its design, rank with Laycock's horsehair loom, which we described in connection with the visit of the Institution of Mechanical Engineers to Sheffield of two years ago. It is really surprising to see what complicated operations mechanism may be made to perform by means of cams, levers, and springs. Mr. Laycock's loom exhibited perhaps a higher intelligence than the chain-making machine, inasmuch that it would select suitable hairs from a bundle, and would refuse to continue the work unless the proper kind were supplied. The chain-making machine, on the other hand, has to deal with a more stubborn material and has to connect each link. We do not know the name of the inventor of this machine, but the chain is known as "Triumph Chain."

FUELS AND THEIR USE.

At the annual meeting of the Society of Chemical Industry, held in London on July 20, the chair was occupied by Dr. J. Emerson Reynolds, F.R.S. He chose, as the subject of his presidential address, "The modern developments in regard to fuels and their use"—a subject, as he explained, which had occupied much of his attention. The address was one of popular, as well as of scientific, interest.

After some preliminary remarks, Dr. Reynolds said:—

The fuel question is one which concerns those of us who live on the western side of St. George's Channel even more seriously than it does you, as our coal beds have been washed away in ages past, and of native fuel there is practically none save peat; hence industries which require large quantities of cheap coal cannot flourish in Ireland under existing conditions. It is, therefore, our interest to watch closely the development of improved and economical methods of using such fuel as we can obtain from other countries, and apply them in the utilization of our bulky but abundant peat. It is evident that no other fuels need be considered save coal, peat, and petroleum; hence, my remarks can take somewhat the form of a trilogy, minus the dramatic element, precedence being given to the solid fuels, and the first place necessarily to coal. . . .

The Royal Commission on Coal Supply, which commenced its sittings in July, 1866, and reported in July, 1871, after inquiring into all probable sources of coal in Great Britain, arrived at the conclusion that not more than 146,480 million tons were available at depths not exceeding 4000 feet from the surface. Therefore, at our present rate of increase of population and of coal consumption, our supply would not last for 230 years. But Mr. Hall, one of Her Majesty's Inspectors of Mines, who has special experience of coal mining, forms a much lower estimate of the supply practically available with our present means, and considers 170 years as the more probable duration of our coal beds. This estimate is based on fuller information than that possessed by the Royal Commissioners; we are therefore justified in concluding that the inhabitants of Great Britain 170 years hence will have little, if any, home-raised coal to burn if we continue to use it in our present wasteful fashion.

It was pointed out by the Royal Commissioners in 1871 that we cannot suppose 'the production of coal could continue in full operation until the last remnant was used, and then suddenly cease. In reality a period of scarcity and dearness would first be reached. This would diminish consumption and prolong duration; but only by checking the prosperity of the country.' . . . . 'Much of the coal included in the returns could never be worked except under conditions of scarcity and high prices. A time must even be anticipated when it will be more economical to import part of our coal than to raise the whole of it from our residual coal-beds.' As the area of coal-bearing strata in North America is fully seventy times greater than ours, it is easy to see where our future supplies must come from. The rate of increase in the use of coal has been greater than the Commissioners anticipated in 1871, and Mr. T. Foster Brown, C.E., President of Section F of the British Association at Cardiff last year, has placed on record his opinion that at the end of only fifty years from the present time the increased cost of coal will be severely felt. Pessimism is never pleasant; nevertheless we cannot afford to ignore reasonable inferences from fairly ascertained facts.

I apprehend that there are few ordinary consumers likely to be influenced in avoiding waste by the knowledge that we are within measurable distance of the end of our store of British coal, as that calamity may still be some generations off. But the case is very different with large consumers; the inevitable, if gradual, increase in the cost of coal has effectually arrested the attention of those directly concerned in our great industries or anxious for the maintenance of that manufacturing supremacy to which this country chiefly owes its wealth and power. Keen international competition in trade has quickened the effort to get the utmost work out of fuel, and therefore to diminish waste.

No such considerations have, however, produced any effect on the domestic conscience. A spasmodic increase in cost of coal stimulates the use of various economical devices which are almost wholly given up when prices fall back nearly to their former level. A small residual effect is left, which, though slight, is on the right side. But that economy in the domestic use of coal which could not be effected by a patriotic desire to avoid the too rapid exhaustion of our coal beds, or by a fear of permanently dear coal, is likely to be brought about by the growing nuisance of large towns, namely, fog, for whose increase our 'hearths and homes' are in a greater degree responsible than the much abused factory chimneys. The primary consideration in seeking to cope with the fog demon no doubt is to avoid the production of solid particles during the combustion of any fuel we may use, hence that method which avoids the formation of smoke at any time, and is both more convenient and economical, must ultimately 'hold the field.' As you well know, various suggestions have been made for the purpose of avoiding the production of smoke, and it has even been proposed that the use of non-flaming coal should be made compulsory in all large towns, notwithstanding the difficulties known to attend the combustion of anthracite or similar substances in open grates. But even if the fog demon could be satisfactorily exorcised by such means, the fact would remain that the combustion of any solid fuel in an open grate is a most wasteful proceeding. On the other hand, closed grates or stoves have not been popular in these countries. How, then, can we combine economy in the use of coal with smokeless combustion and domestic convenience? The answer is sufficiently obvious—we must more or less completely gasify the coal prior to its complete combustion.

The late Sir William Siemens showed us long ago how to convert coal completely into gas by means of his great 'producer' furnaces, and demonstrated the applicability of the comparatively poor 'producer' gas to operations requiring very high temperatures as well as to the minor work of steam raising. Siemens showed that when so used one ton of coal can perform as much work as 1·7 tons directly burned. In such comparisons the 'producer' gas was, of course, burned at a short distance from its source and under the regenerative system. This mode of using coal seems to be the most economical of which we have practical experience; but the gas which is produced seldom contains less than 65 per cent. of useless nitrogen, and therefore is not rich enough in combustible matter for general distribution.

The Wilson method of gasifying coal and that employed by the Leeds forge, permit the production of a richer gas. The Wilson process involves the formation of a certain proportion of 'producer' gas in raising the temperature of the coal up to the point at which it can decompose steam, and then affords a mixture of carbon monoxide and hydrogen, or so-called 'water-gas.' The former can be used for steam raising or furnace work in the immediate vicinity of the producer, while the water-gas can be transmitted through mains as readily as ordinary town gas, and loses nothing by carriage save its initial heat. Thus one general method affords two qualities of fuel and gasifies the coal in an economical manner.

Whether by the Siemens method in its modern form or by the more or less complete conversion into rich water-gas, a great saving in coal can now be secured in almost all large operations requiring the command of high temperatures; and the use of such gaseous fuel is so steadily extending that we may expect in the near future to reach the maximum practicable economy of coal in our greater industries and of smoke abatement as well.

Between the complete conversion of coal into gas and the very partial process included in the production of ordinary illuminating gas is a wide gap which needs to be bridged over in the interests of the small manufacturer and the domestic consumer alike before we can secure that economy in the use of coal which we know to be necessary. For it must be granted at once that our ordinary 16-candle illuminating gas is seldom an economical fuel at an average price of 3*s*. per 1000 cubic feet, though it is capable of being so used as to effect distinct saving under special circumstances. As an example of its economical use, even near the price stated, I may cite the case of the kitchen of St. John's College, Cambridge, where gas and steam have been substituted for coal, and an annual saving effected amounting to about £80. But in establishments which cannot be systematically conducted coal-gas at 3*s*. is too expensive a fuel. Several solutions of this important practical problem have been proposed; one group of suggestions involving the supply of two distinct gases, an illuminating and a fuel-gas, and therefore requiring two sets of street mains; but the progress of electric lighting is so rapid that gas companies would not be justified in outlay of capital on a second set of mains. Another proposal is to supply one gas of high calorific value but low illuminating power at a cheap rate, and this gas, when used for lighting, to be charged at the point of consumption with vapours of suitable hydrocarbides. But the true solution involves a compromise much on the lines along which gas managers are at present apparently working.

You are aware that the average produce of 16-candle gas per ton of coal is about 9500 cubic feet. By the introduction of steam to a small extent the volume of gas can be materially increased, but at the expense of the illuminating power. In order to compensate for this loss, rock or other oils are injected along with the steam, and the illuminating power is maintained. An objection to this practice is that carbon monoxide is present in such gas, but it is also found in many samples of ordinary coal-gas, and provided the gas has a strong and characteristic odour, so that its escape can be readily detected, no risk need attend its use. The supply of the richer bituminous coals is steadily diminishing, hence the practice must grow of supplying a modified water-gas instead of coal-gas as we have hitherto known it. Better far, in the interests of producer and consumer alike, that the inevitable change in the character of the gas manufacture should be carried out with the full knowledge and assent of the public after due Parliamentary inquiry, and in such a manner as to secure the maximum advantage without undue interference with the great monopolies enjoyed by the gas companies. So many satisfactory methods are known by which the illuminating power of a gas can be increased at or near the burner, and gas as an illuminant is moreover being so certainly displaced by the electric light that the objections hitherto urged against the supply of gas of high calorific value but low illuminating power have almost ceased to have any practical force. On the other hand, the supply of a cheap gas of the kind I refer to would prove a great boon to small manufacturers as well as to the domestic consumer, and competent gas engineers inform me that no real difficulties lie in the way.

The rapid extension of electric lighting in our large towns brings us within measurable distance of some such sweeping change in the character of gas used, in its applications, and in its mode of employment, while the existing mains would serve for its conveyance, and comparatively trifling alterations in our domestic appliances would only be necessary.

It is in this direction, then, that the best prospect of solving a considerable part of the smoke fog difficulty seems to lie, and it is in the same direction that we are to look for true economy in the use of coal. The completion of the system of electric lighting in towns is therefore to be desired by the community, not only on account of its great and obvious advantages for illumination, but because it will render possible the provision and distribution of a cheap gas for heating purposes; and the shareholders in gas companies of such fortunate towns should specially rejoice, as herein lies a good prospect not merely of maintaining, but of considerably increasing, their dividends. Gas companies would not only become purveyors of heat energy for domestic use, but for manufacturing purposes as well, not excepting the production of the electric light.

Hence, our duty to posterity and our own immediate interests coincide in requiring the use of more economical methods of using coal, and that which gives promise of the greatest number of advantages involves the conversion of coal as far as possible into gaseous fuel.[1]

I turn now from coal to peat, which is, as you know, a much less mineralized solid fuel. It is obvious that the question of peat utilization is one of much importance in Ireland, as nearly one-seventh of the island is bog. About 1,250,000 acres are mountain bog, and 1,575,000 acres are occupied by flat bogs, which occur over the central limestone plain of the country and stretch away to the north-west. This store of peat is an asset which may become valuable when you shall have exhausted your coal-beds some 170 years hence. We would naturally desire to realize a portion of our assets at a much earlier date, as nearly all the coal used in Ireland must be brought from the eastern side of St. George's Channel. In this fact I think you have some explanation of the depressed industrial condition of the country, as manufactures involving the use of much fuel can only flourish in Ireland if the margin of profit be considerable; where the margin is small and competition keen (as in the greater industries), they must go under in the struggle with manufacturers having cheaper fuel at command. I grant at once that this is no adequate explanation of the absence of many chemical manufactures which do not involve large consumption of fuel, but it is the inevitable result in the cases to which my remarks apply.

Peat alone, however well prepared, compares very unfavourably with coal in several particulars:—

It is a very bulky fuel, in its ordinary condition occupying rather more than five times the space of an equal weight of coal.

2. It contains from 15 to 25 per cent. of water and seldom less than 10 per cent. of ash.

3. At least $2\frac{1}{2}$ tons of average peat are required to perform the same work as one ton of average Staffordshire coal in ordinary fireplaces or furnaces.

Hence the general use of ordinary peat is attended by the disadvantages of requiring much greater storage room than coal, of producing a light and troublesome ash, and requiring more than thirteen times the bulk of coal to produce the same thermal effect. The last-mentioned consideration practically precludes its use in ordinary furnaces where heat of high intensity is required.

Now the force of the first objection to the use of peat, that of bulk, can be materially diminished by mechanical compression. Many excellent examples of compressed peat have been produced at various times, the most coal-like product I have seen being that of Mr. Hodgson, of Derrylea, who compressed, thoroughly disintegrated, and dried peat in heated cylinders, and by partially carbonizing under pressure secured the cementation of the material. Moreover, the ash of such compressed peat was not so bulky as that of the ordinary fuel.

I need scarcely say that the intensity of the heat obtainable with compressed peat is greater than with the loose material, but the actual thermal effect is not much altered, save in so far as the material is drier and therefore less heat is lost in evaporating moisture.

Extended comparative trials of coal and of good dense peat in steam engines have shown that the work done by one ton of peat was not more than 45 per cent. that of one ton of coal; hence if coal were 18s. per ton, peat could not compete with it under the most favourable conditions unless delivered at not more than 8s. per ton. Now the peat used in these trials did not contain more than 12 per cent. of moisture, but as dug from the bog it seldom contains less than 35 per cent. of water, even when cut from a comparatively dry bog; it must then be stacked and air-dried. The present price of ordinary turf delivered at the bog is about 7s. per ton; when to this is added the cost of handling this bulky fuel, and carriage for fifty miles, the cost exceeds 45 per cent. of that of coal even at inland towns; hence there is no real economy in the use of peat of the common kind in ordinary furnaces and grates instead of imported coal.

But the public are led by promoters of peat-manufacturing companies, and others who should know better, to suppose that by certain processes of disintegration and compression peat can be made to approach very closely in fuel value to an equal weight of coal. There is no doubt that a better looking and denser product can be obtained by these means, and one which requires less storage room; but unless artificially dried as well, the actual heating effect of the fuel is not materially altered. I have no doubt that the cost of winning and treating the rough peat could be much reduced by the use of suitable labour-saving machinery; but all methods with which I am acquainted involving artificial drying as well as mechanical compression, have cost so much that the product could not compete with coal at the ordinary level of prices. As I have already said, the Irish peat forms a valuable asset, but one not capable of being realized on any considerable scale at present; at least when used as fuel in the ordinary way as a substitute for coal. But it is possible to so burn peat that it shall compare much more favourably with coal, and this solution of the problem is obtained by converting rough peat into gas.

You doubtless remember that in 1872 the cost of coal advanced even beyond the panic prices which prevailed for a week or two about the beginning of the present year. But the coal famine of 1872 lasted for a considerable time, and serious efforts were then made in Ireland for the utilization of peat. It soon became evident that the continuance of dear coal meant the suspension of several industries and their probable loss to the country; hence, leaving to others the attempts to convert peat into a suitable fuel for general domestic use, I took up the industrial side of the problem.

I saw that the best chance for economically applying peat for most manufacturing purposes lay in gasifying the material in a Siemens furnace, as two special and important advantages must obviously be gained thereby:—(1) The use of peat in the rough state without artificial drying; (2) The avoidance of the injurious effects of abundant ash by burning the peat-gas at some distance from its source, and under such conditions that the comparative value of coal and peat should be nearly in the proportion of their percentages of carbon. I therefore moved the Royal Dublin Society to appoint a committee of engineers and other scientific men to have the value of peat tested in the way proposed. The outcome was that the directors of the Great Southern and Western Railway of Ireland, acting on the recommendation of the able locomotive engineer, Alexander Macdonnell, C.E., decided to erect a complete Siemens regenerative gas furnace for working up scrap iron in their engine factory at Inchicore. This furnace was supplied only with rough peat, often containing as much as 38–40 per cent. of water, but no difficulty was found in keeping the welding chamber at a bright white heat for months at a stretch. The average consumption of fuel was 5·09 tons of peat for each ton of iron forged from scrap to finished work. Before the Siemens furnace was built the ordinary air furnace fed with coal was employed, and the average consumption per ton of iron was 4·96 tons of coal. I need scarcely say that peat is practically useless in such a furnace. Therefore peat used in the gas furnace as compared with coal in the ordinary welding furnace not only proved in practice to answer extremely well, but performed 97 per cent. of the work done by an equal weight of coal. As the price of peat was about half that of coal at the time, Mr. Macdonnell estimated that a saving of £4 7s. 9d. per ton of finished forgings was effected. If therefore the coal beds were exhausted we have a good substitute in peat for operations in which a very high temperature is required, provided the fuel is used in the gas furnace or according to some similar plan.[1]

The above remarks refer to work done twenty years ago. Now, thanks to the valuable investigations of Mr. Ludwig Mond, F.R.S., detailed in his Presidential Address of 1889, the pro

[1] Since the above was written I have seen a short abstract of Mr. Valon's address to the Institute of Gas Engineers, in which I am glad to find that he takes a somewhat similar view of the situation to that expressed above.

[1] Of course the comparison is more favourable to coal when the latter is used in the Siemens furnace, as it is found that a ton of iron required an average of three tons of coal, therefore the work done by peat was about 60 per cent. of that by coal under the same conditions.

duction of ammonia from peat along with gas according to his method will probably pay for gasifying the fuel and materially facilitate the utilization of peat.

Much to my surprise and regret this work remains the sole practical outcome of our efforts in the direction of peat utilization during the fuel famine of 1872, so far as Ireland is concerned. Manufacturers now know how they can economically use peat for high temperature operations, and Dr. Bindon Stoney, F. R.S., has suggested that peat should be gasified at the bogs and carried to convenient centres of industrial activity. This could undoubtedly be done, especially if instead of 'producer' gas a fuel were manufactured approaching water-gas in composition, and such a gas of good calorific power can be manufactured from peat. Thus, as in the case of coal, peat could be made economically to provide ight and heat energy as well for domestic use as for manufacturing purposes. Would that we could apply even a small portion of the energy stored up in peat to stimulate those who should be most active in utilizing in the best and most economical way the abundant material almost at their doors!

If, then, there are many and great advantages in converting our bulky solid fuels into gas and distributing them in that form for heating purposes or supplying power by means of gas engines, it is clear that such advantages must be confined for the most part to towns or special manufacturing centres unless the gases are condensed to the liquid form, and so rendered portable to considerable distances; but nature has already done a great part of this work for us in providing the wonderful material we call petroleum. I do not think 'wonderful' is too strong an adjective to apply to this material, whether we consider its nature, speculate as to its probable origin, or attempt to measure its value in the world's work; and in this, the concluding section of my address, I propose to sketch in broad outline the main points of public interest which relate to this, the most important of our liquid fuels. . . .

The views of geologists as to the nature of the general process by which petroleum is formed are elaborately discussed in the eighth report of the United States Geological Survey, and the conclusions are there carefully summarized (page 506). In substance they are as follow:—That petroleum is derived from organic matter by a process of slow distillation at comparatively low temperatures: that the organic matter was not in all cases of vegetable origin, but was in some instances derived from animal substances in contact with limestone; and, finally, that the stock of petroleum in the rocks is practically complete. It follows, of course, that the supply is exhaustible, but geologists do not even guess at its duration.

In contrast with all this is Mendeleeff's view that petroleum is not a product from organic material, but is chiefly formed by the action of water at high temperatures on carbide of iron, which he supposes to exist in abundance within or below the earth's crust. The cracks and fissures caused by the upheaval of mountain chains permit water to reach the heated carbide at great depths, and carbides of hydrogen result in accordance with the general equation—

$$3\,Fe_mC_n + 4\,mH_2O = mFe_3O_4 + C_{3n}H_{8m}.$$

The hydrocarbides then distil up and condense within the cooler sedimentary strata. The occurrence of petroleum in active volcanic areas, as in Sicily and Japan, is held to accord with this hypothesis, which latter is also consistent with the remarkable fact that rock oil is usually found in the vicinity of mountains. But my chief reason for referring to this attractive hypothesis is that it permits us to suppose the hydrocarbides are still being formed within the earth's shell, especially beneath the geologically modern mountain chains, and that the supply of petroleum is practically inexhaustible. Whether that view can be sustained we must leave further evidence to decide, and now return after this digression to the consideration of the material itself.

The porous strata saturated with petroleum often lie at considerable depths below the surface soil of the district, and the oil is in many cases prevented from rising by a bed or shell of almost impervious material. In boring for the oil this enclosing shell is penetrated and the result often is the ejection of a column of liquid rising as a fountain of several hundred feet into the air. This violent expulsion of petroleum is due in great part to the pressure of pent up gases, and the crude liquid always contains some of these gases in solution. In some instances gas only issues, and a so-called 'gas well' is obtained, from which are emitted enormous volumes of marsh-gas and its lower homologues, as well as hydrogen. Some of these American gas wells afford from 10 to 14 million cubic feet per day, delivered at a pressure of as much as 400 pounds to the inch. Such gas is a fuel of high value and, as you know, has been largely utilized for industrial and domestic purposes at such great industrial centres as Pittsburg.

One million cubic feet of the natural gas obtained from the Trenton limestone at Findlay, Ohio, are said to do the same amount of work in heating as about 60 tons of Pittsburg coal. Some of these gas wells have been exhausted, but others have continued in full productiveness for several years. Although this natural gas is compressed and transported in cylinders to considerable distances, it evidently must remain of almost exclusively local value; not so the liquid petroleum which issues along with it or in its immediate neighbourhood. This is the most portable of all fuels obtainable in nature, and therefore is the most convenient means by which light and heat can be transmitted to all parts of the world—hence it is of greater practical interest to us than the natural gas.

You are aware that the hydrocarbides of which the American petroleum consists chiefly belong to the saturated group C_nH_{2n+2}, whereas those of Russian petroleum are mainly benzenoid hydrocarbides of the general formula C_nH_{2n}, isomeric with the olefines, but really hydrogenized aromatic compounds of the naphthene series. Petroleum from both sources affords some of the lower homologues of marsh-gas, hence in the process of refining crude petroleum by distillation the first products consist largely of butane, pentane, and hexane, which are separated and condensed by pressure, the product being used for refrigerating purposes, owing to its high volatility. Between 80° and 120° American petroleum affords a spirit of specific gravity about 0·75, and above 130° the illuminating oils are obtained, whose gravities vary about 0·8, while the residue which is not vaporized at 300° includes the heavier lubricating oils, which are also admirably suited for use as fuel, and are cheaper than those generally used for lighting purposes. During this process of refining by simple distillation there is always more or less decomposition in progress, hydrocarbides of high molecular weight being resolved into simpler ones at a comparatively high temperature; and when crude petroleum or its constituents are rapidly heated, this resolution can be carried so far as to convert a large proportion of the oil into permanent gas, valuable alike for illuminating and heating purposes. Thus petroleum is a fuel which can be permanently gasified with facility, and is no doubt wholly converted into gas just prior to combustion in our common lamps.

Several methods are employed for the conversion of oil into rich gas, and storing the latter for distribution through tubes in the ordinary way. In one class of such processes the oil alone is rapidly heated to a temperature of from 800° to 1000° in iron retorts, as in the methods of Pintsch and Keith, thoroughly described by Dr. Armstrong in vol. iii. of our Journal. The yield of gas seldom exceeds 130 cubic feet per gallon, as liquid hydrocarbides of low boiling points are condensed chiefly during the compression of the gas into cylinders for use in railway carriages. The gas is rich in carbon compounds, including methane, ethylene, and crotonylene, and its illuminating power, even after compression, is seldom less than forty-five candles. I may add that Mr. Ivison Macadam has given in vol. vi. of our Journal (p. 199) a valuable series of observations on the gas-producing power of various oils treated by a process very similar in plan to that of Pintsch.

Another mode of converting petroleum into gas includes the use of steam, as in the process of Messrs. Rogers, of Watford, who inject the oil into red-hot retorts by means of steam, the latter appearing to facilitate the permanent change of the petroleum without the formation of much carbon monoxide. The gas so produced is said to amount to about 140 feet per gallon of heavy oil used, and has, according to Mr. Rowan (this Journal, vol. vii), the following composition:—

	Per cent.
Hydrogen	31·61
Marsh-gas	46·17
Illuminants	16·29
Carbonic oxide	0·14
Nitrogen	5·06
Oxygen	0·73

This gas is stated to have an illuminating power of fully 56 candles, and to lose little either by standing or by carriage to considerable distances.

As such petroleum gas has about 3·5 times the illuminating power of 16-candle coal-gas, it follows that, so far as illuminating purposes are concerned, the gas producible from one gallon of oil by this process is equal to some 525 cubic feet of coal-gas of 16-candle value. I shall later on refer to the heating value of this petroleum gas, but I have now justified the statement with which this section commenced, viz., that petroleum is virtually liquefied gas in a peculiarly portable condition. Hence in all states petroleum can be used as an illuminant as well as a fuel, whereas coal and peat can only be used as illuminants in so far as they can afford carburetted gas.

Let me now proceed to justify the further statement that petroleum is the most concentrated, and, on the whole, the most portable of all the natural fuels met with in considerable quantities.

Weight for weight the efficiency of liquid petroleum in steam-raising is much greater than that of coal. The estimates of relative value necessarily vary with different portions of the crude material used, and with the quality of coal employed in the comparative trials; hence some of the statements of results are often rather vague. Thus M. d'Allest found that one pound of refined petroleum evaporated 12·02 pounds of water, while only 6·5 pounds were evaporated per pound of a rather poor steam coal. The American results with crude petroleum and Pittsburg coal gave respectively 15 and 7·2 pounds of water per pound of fuel. Prof. Unwin has recently compared petroleum with Welsh coal in steam-raising, the oil being injected by a steam jet through a highly heated coil and then burned perfectly with a clear flame. In his trials with a not particularly efficient boiler he found that 12·16 pounds of water were evaporated per pound of petroleum, and this result he considers about 25 per cent. better than that afforded by the steam coal. These results agree with those of M. d'Allest so far as the effect of petroleum is concerned, but the coals compared were different in value for steam-raising. Hence for an average coal the proportion is nearly three to two; in other words the practical heating effect of one ton of coal can be obtained by the combustion of only two-thirds of a ton of petroleum, while the comparison with the heavy oils would probably be still more in favour of liquid fuel. Petroleum has another advantage over coal in the matter of storage room, as one ton of the liquid occupies only four-fifths of the space of the same weight of coal, so that the bulk of the petroleum required to perform the same work in heating as one ton of average coal is little more than half that of the latter. It follows that a steamer constructed to carry 1000 tons of coal could, if provided with suitable tanks, carry 1200 tons of petroleum, equal in fuel value to about 1900 tons of coal. In addition, the liquidity of petroleum permits it to be pumped and conveyed long distances by gravitation in tubes so that its transport in bulk and in detail is easy. Therefore petroleum is not only a much more concentrated fuel than coal, but it is eminently portable as well and convertible with much greater facility into permanent gas. Against these advantages must, however, be set the inflammability of petroleum, and consequent greater risk of fire.

Now we have to consider the question of relative cost of petroleum used as fuel in liquid or gaseous form as compared with coal—the latter being our standard for reference as in the case of peat. We have already seen that about two-thirds of a ton of petroleum can do the same amount of work in heating as one ton of coal; therefore petroleum, when burned directly, cannot economically replace coal unless two-thirds of a ton of the liquid can be purchased for less than the cost of one ton of coal. We know the cost of ordinary lamp petroleum in these islands is at present far beyond that limiting value; even the heavy oils which are not good enough for lamps, and yet are too 'thin' for lubricants, only compare favourably with coal where the latter has to be carried long distances, and is therefore dear. However, all practical difficulties having been overcome in the use of these heavy oils for steam-raising, a comparatively small advance in the general price of coal would at once render them economical for industrial use as fuel.

But when we compare petroleum gas with ordinary coal-gas the comparison is much more favourable to the liquid fuel; unlike coal, petroleum is already more than half-way on the road to conversion into gas. As you know, one ton of coal affords about 9500 cubic feet of 16-candle gas. On the other hand, one ton of oil of sp. gr. 0·85 can afford about 24,000 cubic feet of gas, having an average illuminating power of 60 candles, or the equivalent of about 70,000 cubic feet of 16-candle value, and this rich gas admits of preparation on the small scale suited to country places, while the retorts used in the production of the gas can be heated by petroleum. The petroleum gas of some 60-candle power is said to be producible at about 6s. per 1000 cubic feet. If we were to assume that the calorific value of the gas is directly proportional to its illuminating power the cost would correspond to about 1s. 7d. per 1000 cubic feet of 16-candle coal-gas. But the facts do not justify the assumption, as the calorific value of methane is known to be greater than that of the heavier carbides to which the high illuminating power is due; hence the comparison is probably less favourable to petroleum gas by about 25 per cent., though further experimental evidence is wanting on this point. However, even after this deduction, petroleum gas is the cheaper fuel as well as illuminant.

The necessary links between the elements of the trilogy on coal, peat, and petroleum are now, I think, sufficiently evident. If we desire to use each fuel in such a way as to develop most economically and conveniently its store of heat energy, we must first partially or perfectly gasify it. The newest member of the triad—petroleum—is the one which lends itself most easily and completely to such treatment, in consequence of its physical condition and chemical characters. It is also the material that we must expect to facilitate the production of cheap gaseous fuels from coal and peat which shall at the same time possess sufficient illuminating power for most purposes. Chemical industries would probably benefit to a greater extent than others by the supply of cheap fuel of the kind in question; hence I have ventured to tax your patience by dwelling on this topic in your presence to-day.

SUGAR-CANE BORERS IN THE WEST INDIES.

MR. BLANDFORD'S report on sugar-cane borers, published in the *Kew Bulletin* for July and August last, deserves more than a passing notice.

The report contains a plate of the insects in question, which will render their identification easy.

The first is a caterpillar and moth, *Chilo saccharalis;* the second a weevil, *Sphenophorus sacchari;* but the principal attention in the report is paid to the shot borer, *Xyloborus perforans*, a beetle which has lately caused considerable loss to growers of sugar-canes in Trinidad. These losses have been so large that on some estates thirty per cent. of the sugar crop has been destroyed, and in some fields fifty per cent., presumedly by the devastations of this beetle.

This beetle *X. perforans* is to be found over a very large area in the tropics; it is the same species that has done so much damage to wine and beer casks; it has been found in India, the Malay Archipelago, Madeira, Mauritius, North and Central America, Brazil, Guiana, Peru, and probably in Australia, so that no sugar-producing country can consider itself free from the fear of its ravages.

Mr. Blandford's report is interesting and valuable, not only for the amount of information it gives relative to this most destructive insect; but also for the way in which he points out what remains still to be investigated on the subject; so that it not only furnishes valuable information to the planter in the West Indies, but also tells him what course his further investigations should take; and it might well serve as a model to future observers in drawing up similar reports.

"The chief subject for investigation," to quote Mr. Blandford, "is the relation of the insect's attacks to the health and condition of the canes, whether it (the shot borer, *X. perforans*) is a true destroyer, or merely a follower and manifestation of antecedent and more serious injury:" this question, Mr. Blandford says, "I do not attempt to solve; it can only be studied in all its bearings by observers on the spot;" and he further gives a list of definite points which require inquiry and solution.

There is no doubt that the presence of *X. perforans* is usually accompanied by the sugar-boring caterpillar, *C. saccharalis*, and the weevil, *S. sacchari*, and also with fungoid growths, which may of themselves account for the acidification of the juices of the cane, which is apparent in canes attacked by the shot borer; but whether or not the shot borer attacks healthy canes is a question on which there is much diversity of opinion, and we hope that bringing the question before our readers will lead to