The Chairman: I regret the fact of Mr. McTaminey not being present to answer any questions on his interesting Paper on the Solid Injection Oil Engine just read by our Hon. Secretary, but understand he will be pleased to reply to any queries that may arise from the discussion. The feature of Solid Fuel Injection is doing away with the complication of Air Compressors as required in the original Diesel Type Engine, and although a number of vessels installed with engines of the type are giving satisfaction on long voyages, it is evident that a process of simplification is in being among British engineers such as took place on the introduction of the Compound Steam Engine. From all I hear, the working and maintenance of large Marine Oil Engines is readily acquired by Marine Engineers, and some ships are running successfully with engineers transferred from steam vessels to oil engined vessels in the same company. In view of the importance of the paper and the object of obtaining as much information as possible, I would suggest remarks in discussion be kept closely to the subject before us and that there will be some useful matter for the Transactions as regards the working of Marine Oil Engines both with solid and air injection of fuel to the cylinders.

Mr. J. L. Chaloner: The paper under discussion represents a whole mass of common sense, and from that point of view it is a most valuable contribution to the papers which have been read before this Institute on this subject.

If there are any manufacturers of air compressors here to-night they will probably feel somewhat anxious with regard to the future prospects of this branch of industry. At the same time there appears to be a good opening for these makers as marine engineers, because the paper has clearly shown that the marine oil engine may be run with very little knowledge of this class of engine.

Although the paper is discussed under the heading of "The Solid Injection Engine," I would personally object to the use of such a term. One has always heard the words "solid injection" coupled with "solid exhaust" and as the nomenclature of the oil engine generally has suffered very largely, there is some justification, I think, to use the term "mechanical injection," which after all is a more correct technical interpretation of the system under discussion.

Going back to the last paragraph of the paper, the author states that "the solid injection, whatever may be advanced against it from the theoretical side, is undoubtedly a working proposition." It is not intended to discuss the theoretical aspect of the problem, but I would like to state that from a theoretical point the mechanical injection engine can be proved to be more efficient than the air injection type.

Examining for a moment an ordinary diagram (Figure 1) of a heavy oil engine we can refer to point A on the diagram as the cut-off point similar to the cut-off point in the ordinary steam

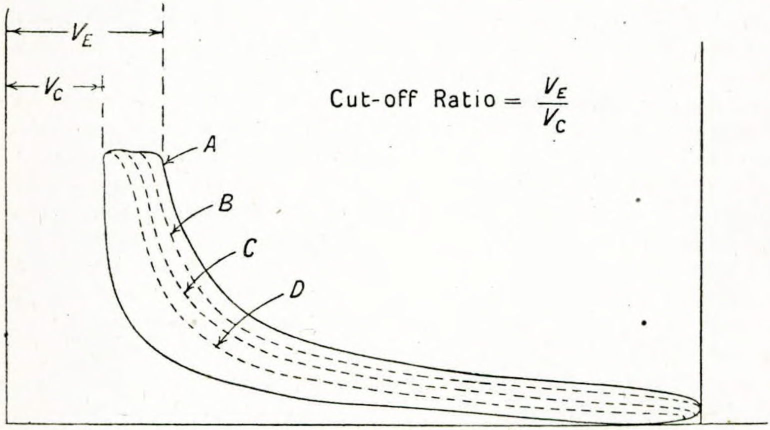


Fig. I.

engine. It can be proved that the thermal efficiency increases with a smaller cut-off ratio and an actual experiment gives the following results :—

Load.	Full Load,	¾ Load.	½ Load.	¼ Load.
Diagram	A	B	C	D
Cut-off Ratio from indicator diagram..	2·45	2·11	1·56	1·39
Thermal Efficiency...	51·4°/。	52·4°/。	55·75°/。	60°/。

Owing to the absence of the cooling effect of the expanding injection air and owing to the consequent smaller amount of heat to burn the fuel, the cut-off ratio in a mechanical injection engine is lower, with a corresponding increasing thermal efficiency.

From a technical point of view we have to deal with the question of atomisation and turbulence. It is stated as a fact that the expanding air increases in volume something like 75 times its original volume, thereby producing the atomising effect. However, it should be remembered that the oil on being heated expands and the relative volume of a globule of oil in the solid and gaseous state is something like 160. Although it is recognised that in the available time the oil cannot be gasified completely, the available temperature is sufficient to gasify a proportionate volume of oil to give approximately the same increase in volume as the expanding air, hence a similar atomising effect can be produced

In my discussion on Mr. Peel's paper I went into the question of heat transference from the heated air compression to the oil globule and there is, therefore, no necessity to go into this point again. There is, however, no doubt that the required amount of atomisation and accompanying turbulence may be produced equally efficiently with mechanical injection as by the air injection system. The question is then asked as to why with equally good combustion the fuel consumption in a mechanical injection engine is not lower in proportion to the increased mechanical efficiency between the two types of engines, which owing to the absence of the air compressor is improved from 75 per cent. to about 83 per cent. Whilst it is admitted that in certain instances the mechanical injection engine has not reached the same fuel consumption as the air injection engine it has been proved that under certain conditions the mechanical injection engine can deal with heavier, *i.e.*, inferior, fuels than the air injection engine. We should remember that after Ackroyd Stuart recommended the mechanical injection system, Diesel recommended the use of the air injection system which was adopted universally. Continental and other manufacturers who tried the mechanical injection method condemned it as a failure, and not until the British oil engine industry took up the matter seroiusly has it been proved that there is a practical solution to this important system. The possibilities of using a valveless engine (either simple or compounded) offer a great inducement to us to study this important system. Its construction will be simple, thereby increasing its reliability and facilitating easy manipulation on the part of the personnel.

I am sorry the author did not touch on the question of fuels. He gives no indication of what fuels he has been employing. I would suggest that such information is invaluable in order to make a complete survey of this important problem. The marine engineer can give most instructive information to the designer and manufacturer by making notes and records of his practical experience. Only by such co-operation will it be possible to design an engine which will be equal, if not superior, to the general behaviour of the modern steam engine.

There are in this country under construction five designs of mechanical injection engines for stationary purposes and three for marine purposes. I believe that in Germany there are three manufacturers actively engaged to-day, whilst in America we have five further manufacturers who all believe in the ultimate success of the mechanical injection engine. Whilst these manufacturers represent a very small nucleus of the total firms engaged in this industry their efforts indicate the tendency of design and it is out duty, not only from a commercial but from a national point of view, to fully investigate all the problems—and of which there are a great many—connected with the mechanical injection engine in order that manufacturers in this country may be able to compete successfully with the efforts which are being made, and which will continue to be made, very vigorously in other industrial countries.

Dr. W. R. Ormandy: As a visitor may I be allowed to make a few remarks? I think my only qualification possibly to become a member of your Institute is due to the fact that I am captain, general engineer and half the crew of a 15-ton boat, which has an internal combustion engine. My experience is not that of the author of the paper when he says his reversing gear generally works. Mine generally does not. The paper is of great interest and has obviously been written by a practical engineer who has much more interest in the £ s. d. side of affairs than in the scientific. He does not know exactly what goes on in the cylinders and really he does not care. But, on the other hand, we who are interested in the development necessarily should care and endeavour to find out what it is that takes place inside the cylinders. The author does not mention the type of fuel employed. The situation in the world to-day is that the amount of oil available for fuel purposes sufficiently high to overcome the inherent difficulty introduced by the expansion and consequent cooling of the injection air, which unfortunately brings down the temperature at the very point where ignition has to commence. This necessitates a compression which is greatly higher than that theoretically necessary to bring about spontaneous ignition of the fuel. What we should like to know regarding the solid injection engine, or better called the mechanical injection engine, is whether fuel, injected though it be at pressures up to 7,000 lbs. per square inch, is really atomised or whether it proceeds across the cylinder in the form of continuous needles of liquid fuel. This makes a very great difference. The more efficiently a fuel can be atomised the more rapidly it will burn. Mr. Chaloner's explanation of how mechanical injection brings about that degree of pulverisation which is in some degree commensurate with that brought about by air injection is very interesting and would be valuable material for use by gentlemen engaged in selling mechanical injection engines. Unfortunately Mr. Chaloner gives no proof that the injected fuel is atomised, and if it exists as a needle of liquid it has to be vaporised and the rate of combustion is largely dependent upon the rate of diffusion of the air into the gas envelope which occupies the place of the thread of oil ejected from the nozzle. If you can get a spray the surface exposed is much greater than is exposed by the same weight of oil in the form of a cylindrical thread. It is interesting to note that if two vaporisers or atomisers give particles having diameters in the ratio of 1 : 2 that under the same conditions of compression and temperature the chances of the oil being burnt in the two cases are in the ratio of 1 : 16. Fine pulverisation of the fuel diminishes the probability of the formation of hot spots on the cylinder head or walls or combustion top. I am absolutely in agreement with the previous speaker in considering that the future is in the hands of those who go in for solid injection. It is right in principle, and it is only a question of mechanical adaptation that will enable us to achieve results by it. In fact, I think they have been already achieved. What is required is an engine that will be capable of using the widest range of oil, which shall have the highest thermal efficiency and be capable of allowing increase of cylinder size. If the temperature in the interior of the cylinder is too high the skin surface of the steel or iron is raised to a very high temperature, and before the heat can be carried away the expansion of the top layer of iron or steel has been carried beyond the modulus of elasticity and the iron or steel becomes covered with extremely minute cracks. This was found to be the case in an engine built by Junkers. That apparently limits the temperature that can be attained in the interior of the cylinder. That is the view entertained by Junkers.

The CHAIRMAN: The last speaker has no need to apologise for the very valuable remarks he has made. I think the initial and upkeep costs are two important features, and any information on this point will be of value, because a good many people are enquiring as to the cost of upkeep and the time required for repairs in port. You have to consider all these things in regard to the value you are going to receive in service. I have also heard of requirements for a standard Diesel Engine fuel oil, as there are great differences in the characteristics of available fuels; in this it is reasonable that the engine that can work on the widest range with minimum adjustment will be the type that will find favour for marine propulsion.

Mr. G. Plows: Referring to explosions of intercoolers on air compressors, I have found from experience that the water-cooled copper coil type gave considerable trouble owing to the large second stage coils (20 atmos) vibrating against the sides of the water jacket, thus causing a wasting and leakage of the coil. After an explosion of a third stage coil (60 atmos) the remainder of the coil was examined, and it was found that the hot compressed air had severely scoured the internal wall furthest from centre of the coil, down to a dangerous thickness; owing to the above scouring effect on the coils, it was found essential to frequently remove them for a weight test.

Dr. W. R. Ormandy: The author states they were carrying oil for the Government. That would mean oil within the Government specifications for a fuel oil. These are rigid, and it tells us at least that it was oil having properties within certain limit, and that would certainly exclude oil of the worst type.

Mr. B. P. Fielden: I share the opinions expressed by previous speakers that the class of oil should have been mentioned in the paper, and I also think we should have the oil consumption of the *Trefoil*. The author states the bunker capacity and the displacement, but he does not give the oil consumed per brake horse-power, and this is required if comparisons are to be made.

The author mentions in the paper that the engines are not commercial ones but that the *Trefoil's* engines were designed for a special purpose. I think it would have been of greater interest to us if the 1,500 B.H.P. had been obtained on less cylinders. In this ship it required 16 cylinders to develop the power which, in other ships, is obtained from 6 cylinders of larger dimensions, and consequently the mean pressure in each cylinder must have been low and not comparable with the mean pressures of the latest marine Diesel four-stroke engines fitted with air blast injection, as the latter have a mean pressure of from 80 to 90 lbs. per square inch. It is therefore not commercially sound that so many cylinders should be fitted to obtain such a comparatively small horse-power because the cost and weight per horse-power must be high.

I agree with Mr. McTaminey that rotary pumps will be more extensively used in the future owing to their being able to do their work with less overhauling and stoppages for repairs, and where internal combustion engines are used for the generation of electricity the motor driven rotary pump is in my opinion the best type of pump to use for all general services where there is a constant stream of water or oil to deal with.

In a Diesel engined ship I think it is best to drive all the auxiliaries electrically, and we have found that with a Diesel engine driving a dynamo which supplies current to electrically driven winches that one ton of oil is equal to about seven tons of coal. There is a big loss of heat from steam winches and also from the piping connecting these to the boiler.

In regard to Engineers for " Motor Ships," my experience is that those previously accustomed to steam engines soon become expert at handling internal combustion engines because they are interested in their profession and in new engineering problems generally.

Mr. F. O. Becket: Mr. McTaminey states: " The Vickers' engineers claim that the solid injection system will give at least as good consumption as air injection in similar circumstances, and judging from the *Trefoil's* running which took place on any service fuel that we happened to be carrying for the fleet." Mr. McTaminey has evidently struck the right chord and I very much welcome this contribution based upon his experience, and give credit to him, as we do to the early pioneers who went through this world in the early days in the steam engined ship, from the *Savannah*, in 1819, onward. Mr. McTaminey speaks of bell cranks. When I noted this it looked to me as if there might be a possibility of slightly more wear and tear in one set than in another, and it occurred to me whether these are arranged to work automatically to reverse full ahead to full astern in the sixteen cylinders. There is also a reference not quite clear to me where the gear is operated by an air ram, so also as to the oil ram dash pot. The question arises also whether there is a buffer fitted, as we have these on some gears in order not to act too quickly. The pistons are stated not to be water cooled, and I gather that these engines are not for commercial service. The heat of the cylinders becomes very great, I understand, under certain conditions, and it would be interesting to know what causes this, as it sometimes leads to disaster. Is it due to a very thin volume of oil with a gas generated at the walls of the cylinder, or is there any acid action set up from the effect of the condensation and a small portion of oil that may be mixed with it?

The CHAIRMAN: Although the author gives his experience of the solid injection engine and states the fine running made, it is well known that many of the long runs have been made with the air injection engine. There are a number of vessels out of this port making voyages in the Far East trade with excellent results. It is a point between the two principles as to which is the lowest in up-keep cost and the most economical at sea. Mr. Fielden gave some points in regard to the use of oil in discharging cargo, which must be a revelation to many. The oil engine is making progress, and practical experience of running or maintenance that can be added to the discussion will be of value. If you have nothing to say at the moment it may perhaps occur to you later, and any remarks sent in will also receive a reply from the author and be included in the "Transactions," to the benefit of the membership generally.

Mr. W. S. JAMES (Bureau of Standards, Washington, D.C.): There is a Diesel engine of rather unique design now being developed in the United States, a comment on which may be of interest. It is being developed by Mr. Elmer J. Sperry, the inventor of the Sperry gyroscopic compass, as a compound expansion engine. The value of compound expansion in Diesel engines is clearly shown by the indicator card drawn on the blackboard, where almost seven-tenths of the working stroke is at relatively low pressure and the remaining three-tenths at really high pressure. Metal used in strengthening the large size of cylinder required for the low pressure expansion is not needed when the high pressure expansion is carried out in a small cylinder suitable for high pressure expansion. Mr. Sperry has designed and constructed two experimental engines developing about 500 horsepower each, running at about 800 r.p.m. and weighing from 15 to 17 pounds per horsepower, a very material reduction of present practice in Diesel engine design. The great difficulty which has previously been experienced in the compound expansion internal combustion engine has been the design of the transfer valve. The present engines consist of three cylinders on a single crank shaft, a high pressure expansion cylinder, a low pressure expansion cylinder and a compressor cylinder. After the charge in the high pressure cylinder ignites, it expands to a relatively low pressure and then is transferred to the low pressure cylinder through the transfer valve of barrel type, in which it is finally expanded to atmospheric pressure. Immediately after the high pressure cylinder has discharged into the low pressure cylinder the transfer valve is rotated through a small arc and the compression cylinder discharges its air through the transfer valve into the high pressure cylinder for further compression and ignition. The work of the compressor cylinder is therefore recovered in the subsequent expansion in the low pressure cylinder. The thermal efficiency obtained by Mr. Sperry with this engine is from 35 per cent. to 39 per cent.

Mr. J. B. Harvey: The author speaks very highly of the way in which his engines reversed. I am of the opinion it is usually more trouble to get a Diesel engine to go astern after running full ahead with way still on the ship, than it is to reverse a steam engine under the same conditions; for the reason that you have not the same power for starting the Diesel engine. Usually only some of the cylinders are fitted with starting valves; those cylinders have to overcome the pressure on the propeller before it can be started to revolve in the opposite way against the direction in which the ship is going. The author states that if he had 250 lbs. of air it was quite sufficient. It would be interesting to know if all eight cylinders were fitted with air starting valves. If so he had more power than it is usual to fit on the majority of Diesel engines. I have experienced that it is impossible to get a Diesel engine to go astern while the ship is going very nearly full speed ahead, and that the ship must be allowed to slow down herself, otherwise you might use all your air trying to get the engines astern, and then not manage it, with the result that you have not sufficient air to start the engine when the ship has slowed down to a speed at which it is possible to revolve the propeller in the opposite direction.

Mr. J. B. Hall: So far as the discussion has gone we are fully of the view that, practical as the paper has been, we still want to have a vast amount of practical information given to us. This has been clearly brought out bv nearly all the speakers. I am sure that an elaboration by Mr. McTaminey of his own paper, if that were in order, on some of the points that have been mentioned—if it were brought to his notice before he replies, or when he replies, he would give us these facts, and it would greatly elucidate a lot of the points that have been brought out. I think Mr. Fielden has brought out a point and, taken in conjunction with what Mr. Harvey mentioned, it seems to carry great weight, the two together. That is, there must be a very low mean pressure in the cylinders, because from the author's own statement, as Mr. Harvey says, if he has only 250 lbs. of air pressure everything is all right. I think that in many ways Mr. McTaminey could have made his paper, which has been read to-night, a very valuable paper, with the elaboration of these points. There are, as has been remarked by Mr. McLaren, many of us who hope we shall not have to take up the deeper study of these engines for a marine point of view, but, as he says, we never know. A further point that occurs to me in connection with these oil engines is this, that in its simplest form, as a land engine, working continuously in one direction, it usually has an enormous amount of working parts. When we come to the point that as a marine engine it has to work either way, either ahead or astern, it is certain that these parts must be duplicated in many instances. With this in one's mind, and recalling the results that have been obtained by the electrically driven ships of the United States Navy, is it not reasonable to anticipate that in the near future, knowing as we do that the auxiliaries must be electric or steam driven in some way, that a Diesel engine or other oil engine in the ship, running continuously in one direction and generating electric power, is likely to be more the motive power of the future than even an oil engine for the main shaft, and some oil engine or other motive power generating electric current for the deck machinery and the auxiliaries?

The CHAIRMAN: We are indebted to the last speaker for his remarks, and I have no doubt many of the points raised in discussion will be fully answered by Mr. McTaminey. Many questions require answers, and we are only learning from actual running experience. In regard to auxiliary machinery being worked by electricity, that is the case in many large Diesel engined ships. The Diesel electric generator engine responds to requirements of power required for either deck winches, heating or lighting by accurate automatic governing, and there is very little clash between engine and deck departments on the call for power; this arrangement has been working for several years. It might perhaps have been advisable to have had a further discussion later on, but we have a good number of papers on internal combustion engines after this one, and these will probably give an opportunity for many other questions arising from the present paper.

Mr. N. HART: There is a point in connection with this engine which I think should be carefully studied by any land type air injection Diesel engine builders who are contemplating building marine engines.

In the engine here described it will be seen that the r.p.m. are low, and this allows of an increased propulsive efficiency.

With the air injection Diesel engine for land work it is an advantage to have the stroke more nearly equal to the bore, as the fuel burns more quickly, and parts may be reduced in weight, thus the revolutions tend to be greater, which is a disadvantage in marine work.

I believe one of the Continental firms found it advisable to design a new series of engines, having a considerably longer proportionate stroke, thereby keeping up a fair piston speed at low r.p.m. as compared with land engines.

Regarding the weight of solid injection Diesel engines, mentioned by Mr. James, I believe the weight of the submarine type works out about 55 lbs. per b.h.p., this type being designed with a view to lightness.

The CHAIRMAN: The last speaker's remarks on propeller speeds is a very important point. I think it is fairly well recognised by the makers of large engines, but perhaps not so much as it might be by makers of smaller engines. The revolutions of the larger size Diesel ships are comparatively low. As I have mentioned, we have quite a number of papers coming on in regard to internal combustion engines. Mr. McTaminey's paper gives us food for much thought and reflection for the speakers at the later lectures.

Mr. FIELDEN: I should like to propose that a hearty vote of thanks be accorded Mr. McTaminey for his paper. I think he has done very good service to the Institute by writing it. If we could get a few more chief engineers or second engineers actually in service with oil engined ships to write and read papers on their experiences I think it would be a great help to us.

Mr. W. McLAREN: I should like to second that vote of thanks. I see a great number of young faces here to-night. I know that will please the heart of our honorary secretary, to see them among us. I should like that a hearty welcome be given to them.

The CHAIRMAN: I am sure we all heartily reciprocate Mr. McLaren's remarks on seeing a number of young members here. There is plenty of room for discussion on the oil engine, and you will have plenty of opportunity of carrying it out.

The HON. SECRETARY: I shall have pleasure in conveying to Mr. McTaminey the vote of thanks passed to-night. I hope to see him to-morrow and thereafter put before him the views of the various speakers for his reply.

Our annual dinner it has been decided to postpone till January 28th—after all the arrangements had been made for October 29th—on account of the inconvenience caused by the coal miners' strike.

On November 9th we have an illustrated lecture to which ladies are invited, and arrangements are in hand to have a meeting every Tuesday evening on subjects which will be announced in the notices page of our monthly issues.

Mr. J. L. Chaloner, on November 16th, with the co-operation of Mr. Thomas McKenzie, will open the syllabus of papers on oil fuel for the Internal Combustion Engine, as arranged at the Conference held on October 20th.

On November 30th, by the kindness of the Anglo-American Cil Co., a kinema film will be shown on the production of oil.

On December 14th Mr. E. G. Warne is to deal with the lubricating arrangements; on January 4th, February 8th and March 22nd Mr. W. Pollock has promised to give papers on Reversing Installation and Auxiliaries; Messrs. A. W. Bradbury, J. J. Fasola and F. G. Butt-Gow have also volunteered to contribute. Messrs. Cammell Laird and Co. kindly agreed to arrange for a representative to give three lectures or papers on convenient dates.

Our object as set forth at the Conference is to obtain as much information as we can upon the oil engine and its various types, with practical details regarding their working capabilities, in order to give opportunity to those who attend the meetings or read our transactions to become more conversant with the subject for the benefit of all concerned.

We are glad to see Dr. Ormandy here to-night, as some of us had the pleasure of listening to his interesting lecture at the exhibition in Olympia Hall. We also welcome Mr. James and other visitors, and extend to all our invitation to future meetings.

Mr. McTAMINEY's Reply: I beg to express my pleasure at the way in which my paper was received and at the vote of thanks recorded. I will do my best to reply to the questions asked, but I am afraid I must restrict myself to the practical side of affairs and in some cases deal collectively with questions raised.

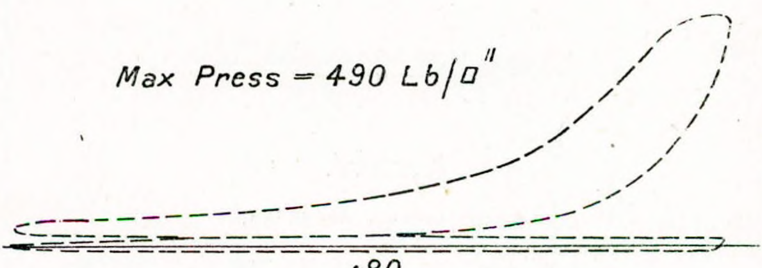
As regards Mr. Chaloner's remarks I use the common term "solid injection" simply because it is easier to say than "mechanical injection," which also is often used. Perhaps a better term still would be "airless injection." Still even that would not prevent people coining catchwords if it suited their purpose. The fuels used in the *Trefoil* varied almost from day to day, and often consisted of mixtures of all sorts of Admiralty boiler fuel, varying from heavy Texas to shale oils. We took fuel oil from tankers and from merchant liners, which carried fuel in D.B.s as cargo from all parts. I do not remember all names of fuel we took from these ships. We supplied the Fleet for boiler use. This same oil fuel we used for our Diesel engines and found it worked all right; no trouble. I hope, however, that the Institute will not be misled into believing that I recommend as an economical proposition the use of the more difficult fuels for marine engines. I think a lot of harm has been done in the past by claiming too much in this direction, and the sea-going engineer and the trade have suffered. There are oils in the hands of Oil Companies which cannot be burnt properly, even under boilers, and many directors who are not engineers will be only too glad to hand these over to engine makers who ask for trouble in the ships they fit out. A marine engine may have to run perhaps three weeks on end and then be liable to stoppages, starts, and reversals at the rate of one a minute for over six hours under the control of a canal pilot. This is very different from land practice. Putting together my experience with what I am told by other marine Diesel engineers, I am strongly of the opinion that overall economy is best served, by avoiding residual oils with considerable incombustible constituents, in marine engines. As certain parts of such fuel cannot be burnt, some use for these should be found. If an engine is used as a cross between a coking retort and a refuse destructor, it must be expected to behave as such. I know of a certain motor ship which has done regular running for some years now, in which it has been found that it is cheapest in the long run to use solar oil. I am not prepared to go quite as far as this, but taking into consideration the present attitude of some organisations regarding work on machinery in port, of which perhaps the less said the better, I would recommend a distillate whenever available. The fuel consumption of a Diesel ship is so small that she has a wide choice of bunkering stations. I may as well say, to disarm criticism, that the ship I refer to has port scavenging two-stroke engines with air injection, and at sea runs at about three-quarters of her rated power.

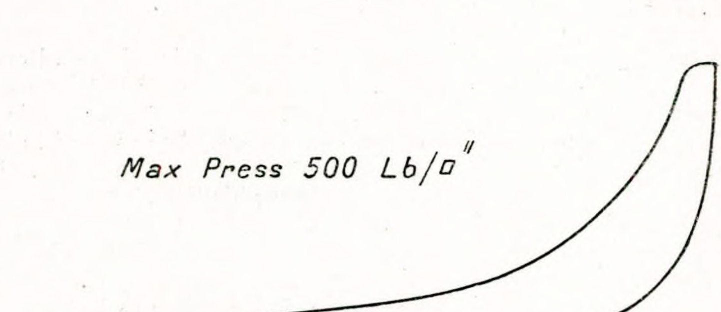
In reply to Dr. Ormandy, perhaps a description of the spray in the open may give him something towards the information he seeks. At the fuel pressures we use (about 4,000 lb.) the fuel comes out in almost uniform needles which will pass through a flame without igniting. At some distance from the nozzle these needles begin to look fluffy, and shortly afterwards rapidly expand into a cloud or mist which floats away. The jet can be ignited if a lamp be applied to it near the fluffy part, and a large sheet of flame like the tail of a comet takes place with a smacking noise. I suppose that when sprayed into compressed air the needle breaks up more quickly than in the open, but I believe an immediate breaking up would not give good results, perhaps because it is necessary to give a good speed to the flame as a whole with fairly high mean pressures. As regards reversing, the compression slows the engine very rapidly after fuel is shut off, and the engine is usually stopped by the time the reversing gear has gone over. The starting air applied for two or three seconds gets the engine running steadily in the opposite direction, after which a couple of cylinders are put on fuel and the rest is a matter of turning the wheel as rapidly as possible. All cylinders are fitted with air starting valves, and I think Mr. Harvey will find this on most marine Diesel engines.

The bell crank bearings do not wear appreciably, as their duty is very low, and as a few degrees variation in the inlet and exhaust valve settings is immaterial, considerable wear would be necessary before refit is required. The dash pot I mentioned is an oil buffer to prevent too rapid a motion of the reversing gear as Mr. Beckett suggests. I am not quite clear as to his question about hot pistons. The *Trefoil* engine is not a commercial engine, but a commercial engine of the same sized cylinder need not have water cooled pistons, and considerably larger engines are running with uncooled pistons. A piston is heated by the flame in the cylinder, and if not cooled internally, must pass most of its heat to the liner. If the cooling water to the liner fails through mud settling in the jacket or through other causes, the heat accumulates in the piston, both liner and piston heat, and the result is like that in an overheated bearing. I don't think there is any question of gases or acids.

As regards the Diesel electric drive mentioned by Mr. Hall, if more than one engine is used for each motor shaft I suppose electrical complications may arise. If a single engine is used, the dynamo and motor seem to form a kind of electrical gear box, and the main advantage is that a smaller engine running at a higher speed than for the direct drive can be used. As long as the engine speed is moderate for its size this sounds quite promising, and I suppose first cost and durability would be the deciding factors. High speed oil engines are apt to be troublesome on long runs, however. Up to 150 r.p.m. or so, in a twin screw ship of ten or eleven knots, can, I believe, be used with propelling efficiencies equal to that of the ordinary single screw steam jobs. Our consumption I reckoned at about ·45 lb. per b.h.p.

I find I have no indicator cards, but I attach a tracing from one of the cards taken on shop test. The indicator rig was none too exact in my ship, so I have also added an actual overload





36 Hours Official Shop Trial

card from the *Narragansett*, a twin screw 6-cylinder solid injection ship of 2,500 b.h.p., which may be of interest, and which I recently managed to get from that ship.

I think Mr. Fielden, in the concluding remarks, is labouring under a misapprehension. The total b.h.p. of the *Trefoil* is 1,500, or about 94 per cylinder. As the cylinders are 17 in. diameter by 27 in. stroke, and run at 150 r.p.m., the mean brake pressure is 80·77 lb. This shows that the rating is higher than in most commercial marine engines. If the mechanical efficiency be taken at 78 per cent., which is probably not far wrong, as no compressors are fitted, the mean indicated pressure would be 103·5 lb.

Lecture.

A Marvellous Magician.

(ILLUSTRATED BY DIAGRAMS AND MANY SAMPLES OF VARIOUS BYE-PRODUCTS AND DYES).

BY MR. J. B. HALL (Member).

Tuesday, November 9th, 1920.

CHAIRMAN: THE HON. SECRETARY.

The CHAIRMAN: The subject this evening has been altered, due to the illness of Mr. G. J. Wells, who was to put before us views of the Lighthouse. Mr. Hall was fortunately able to change the date of his lecture and we are greatly indebted to him for the transfer. I have pleasure in now calling upon Mr. Hall to throw light on the subject underlying his title.

On reading the title of my paper, it is readily to be expected that the members of the Institute, being Engineers, will ask amongst themselves, What has Magic, or a Magician to do with Engineering, which is a reality, every point is visible, and nothing "Kept up one's sleeve."

Be that as it may, the Magician of my story is of vast interest to the engineer, and my only apology for using the title is that, having ladies present as our guests, we should offer such fare as may be acceptable to both the members and our lady friends, not but that we hope in the no distant future to find that, having by easy stages encouraged the ladies inside the portal of theoretical and practical engineering, we shall later have them enjoying a dissertation on the " Theta-Phi diagram " and other similar problems.

When taking the platform to perform some magic, the first thing usually done is to beg from your audience various small items with which to perform. I could not expect to borrow what is on the table, so I arranged to bring my own. These are only small and poor representatives, in part only of what, and with which, the magical metamorphosis was performed.

If any one came this evening expecting to hear a dissertation on some great modern illusionist, I am sorry to say they will be disappointed, at the same time you will all, later on, most certainly agree that no trick of leger-de-main, even when performed by a past master of the art, approaches in the slightest degree to the great magician that I am dealing with. No one ever has, nor I daresay ever will, perform such as the Marvellous Magician of my story.

But " Just as certain things are necessary to the present day magician to arrive at some result, so also was it necessary for my story to have had certain things;

" Just as the Magician requires time to perform his tricks, so was it necessary to have time to perform this magic change and;

" Just as the Magician requires, or uses some method of working, so too has this marvel required some agency."

In regards to the magic referred to in this paper, the four salient points required to be noted are, Time—Pressure—Water—and Heat.

A Metaphorical Hat in which the magic has been performed is too immense to bring into any hall, however large, and varies in size so greatly that one can only suggest, very roughly, such a size as 36,000 feet high or deep and 2,000/3,000 miles across the brim, but this again requires splitting up into several of a smaller size. Even now we do not know how large the Metaphorical Hat is, but the known size is sufficiently large to give us matter for thought, and so small as to leave cause for worry.

Here I have some dead bracken ferns, a very common object of many delightful country walks, some pine cones, some dead leaves, generally accepted as useless dead matter, and I must ask you to imagine these, not as they are, but of very gigantic size. I would not say that these which I have shown you represent all of the material with which the marvel was performed, but they at least were--even if not all—mainly from which and with which the marvel was performed.

Next in order comes Water, and this water was undoubtedly charged with, or carried in its passage over, the masses of dead leaves, etc., minutes particles of clay and earthy matter, and these minute particles gradually deposited themselves by gravitation from the water, whilst passing over these arboreal deposits.

Then in order comes Pressure, and this pressure started from a zero pressure, and gradually increased with the super-added depositions up to an amount which we are quite unable to compute, but which was undoubtedly great, and no doubt was added to beyond all comprehension by a pressure due to the contraction of the Earth in cooling.

Finally, Heat, its temperature and volume unknown, but undoubtedly great, caused in a large measure, chemically, and then you may ask, What is the result? Concentrated sunshine, usually termed COAL, as per the sample.

Thus far, I have brought to your notice the wonderful constructive work of the Marvellous Magician, but the work was not ended here, although in a way it was sealed up here. Thanks to the efforts of our great scientists they have evolved and shown us wonders that we little dreamt of, in a manner somewhat in the style of "Open Sesame!" of the Arabian Nights Tales.

Here let us view some of the results of the work of the scientists of to-day, and what they, with their destructive or analytical work, have produced for our benefit and uses, illustrative of the power of the marvellous Magician—" Nature "—to perform such a feat or series of feats.

Viewing the subject from the question of time, one hardly dares to quote the periods of time mentioned by the great men who give their life study to researches in Geology. They use, and it is generally accepted that in using, as the unit 1,000,000 years their action is justified by the immense periods that must have elapsed. Sir Charles Lyell, a very high authority on Geology, was inclined to estimate the minimum of Geological time at 200 million years. Prof. Huxley calculated that the time represented by the Coal formation alone would be 6 million years. Do we understand what we mean when we say 200 million, or 6 million, or even 1 million? It is easy to write a 1 and 6 noughts and glibly say that is a Million, but its vastness is not actually realised. These statements of estimated and calculated periods of geological formation are not wildly made statements, as geologists have numerous and varied data to go upon. On examining the outer crust of the Earth we inhabit, we find it is not of uniform composition, but consists mainly of distinct layers or strata, lying one over another. This is true, not only of the larger beds or distinct formations, but of the details of each formation, many of which are built up as regularly as the layers of the Great Pyramid: others are made up of layers no thicker than the leaves of a book. Consider what this fact of stratification implies? In the first place it implies deposition from or by water, for there is no other agency by which materials can be sorted out and thrown down in horizontal layers.

The total thickness of Known Strata is about 130,000 feet or 25 miles, or the 1/160th part of the distance from the Earth's surface to its centre; of this:—

30,000 feet belong to the Laurentian	(the oldest known stratified rock).
18,000 feet	Cambrian.
22,000 ,, ...	Silurian.
42,000 ,, ...	Devonian. Carboniferous. Permian.
15,000 ,, ...	Triassic. Jurassic.
15,000 ,, ...	Cretaceous.
About 3,000 feet	Eocene. Oligocene. Miocene. Pleiocene.

and above this comes the Quaternary or recent period, which comprises the superficial strata of modern formation, and is characterised by the undoubted existence of man, and of animals which either now exist, or which have become extinct in quite recent geological times.

The Archaen age lasted 18,000,000 and the Laurentian 18 million years.

The	Cambro-Silurian age lasted probably			12,000,000	years.
,,	Devonian	,,	,,	6,000,000	,,
,,	Carboniferous	,,	,,	6,000,000	,,
,,	Triassic-Jurassic	,,	,,	6,000,000	,,
,,	Cretaceous	,,	,,	3,000,000	,,
,,	Eocene	,,	,,	1,600,000	,,
,,	Pleiocene	,,	,,	1,000,000	,,
,,	Glacial	,,	,,	300,000	,,
,,	Paleolithic	,,	,,	100,000	,,

Here we have a diagram of the Geological Clock of Prof. Lester Ward; also a diagram of Strata.

The best idea of the enormous intervals of time required for Geological changes will be derived from the "Coal Measures," yet these consist of part only of one Geological Formation known as the Carboniferous. These Coal Measures are made up of sheets, or seams of condensed vegetable matter, varying in thickness from less than an inch to as much as 30 feet, lying one above another, separated by beds of rock of various composition. As a rule every seam of coal rests upon a bed of clay, known as the under clay, and is covered by a bed of sandstone or shale. These alternations of clay, coal, and rock are often repeated a great many times; in some sections in South Wales and Nova Scotia there are as many as 80/100 seams of coal, each with its own under-clay below, and sandstone or shale above. Some of the coal seams are as much as 30 feet thick, and the total thickness of the "Coal Measures" is, in some cases, as much as 14,000 feet.

Consider what these facts mean? Every under-clay was clearly once a surface soil, on which the forest vegetation grew, which accumulated debris formed the overlying seam of coal. The under-clays are full of the fibres of roots, and the stumps of trees which once grew on them, and are now found "in situ" with their roots attached just as they stood when the tree fell. Under the microscope it is found that these ancient forests consisted mainly of trees like gigantic club mosses, mare's-tails and tree ferns, with a few resembling yews and firs. In many cases the bulk of the coal is composed of the spores and seeds of these ferns and club mosses, which were ripened and shed each year, gradually accumulating into a vegetable mould, just as fallen leaves, beech-mast, and other debris gradually form a soil in our existing forests. The time required must have been very great to accumulate vegetable matter, principally composed of fine spore dust, to a depth sufficient under great compression to give even one foot of Solid Coal.

Sir J. W. Dawson says:—" We may safely assert that every foot of thickness of pure bituminous coal implies the quiet growth and fall of at least 50 generations of Sigillaria, and therefore an undisturbed condition of forest growth enduring through many centuries. But this is only the first step in the measure of the time required for the formation of the " Coal Measures." Every seam of coal is, as was stated, covered by a bed of sand or shale, *i.e.*, of water borne material. This is accounted for in one way only—the land surface in which the forest grew subsided gradually, until it became first a marsh, and then a shallow lagoon or estuary, which silted up by degrees with deposits of sand or mud, and finally was upraised until its surface again became dry land, on which a second forest grew, whose debris formed a second coal seam, and so on, over and over again until the whole series of Coal Measures had been accumulated, when this alteration of slight submergencies and slight rises came to an end, and some more decided movement of the earth's surface in the locality brought about a different state of things. Taking the assumption that one foot of Coal represents fifty generations of Coal plants, and that each generation of Coal plants took 10 years to come to maturity, an assumption that is very moderate, and taking the actually measured thickness of the coal measures in some localities at 12,000 feet thick, Prof. Huxley calculated that the time represented by the Coal formations alone would be Six Millions of Years. This figure is quite sufficient to show that when we deal with Geological time, the standard by which we measure must be one of which the unit is One Million Years.

Prof. Arber writing on the Natural History of Coal:— " Emphasises the view that different kinds of Coal have been formed in different ways—some having been derived from decay of vegetable matter on the spot where the fuel is now found, whilst other Coal must have been formed from drifted vegetation."

I must pass somewhat hurriedly over the question of Pressure required to consolidate the mass into coal, as also the question of Heat, as I want to spend a little time with the contents of the cabinet.

Strata are consolidated chiefly by pressure, and chemical decomposition and re-composition. The amount of pressure must ever be an assumed amount, and quite unregisterable, as we have not only the pressure due to superincumbent strata, but a pressure due to contractive force in the cooling of the Earth's crust by the radiation of the proper heat of the Earth into space, the result being that over broad areas, rocky masses have been contorted, and compressed, to a great degree, and mountain ranges upheaved. An example of the pressure due to superincumbent strata as measured from the depth of one of our deepest worked coal mines—The Ste. Henriette mine at Fleury in Belgium. This mine is 3,773 feet deep, and assuming that 16/18 cubic feet of earth weigh 1 ton, this would give the weight of the superincumbent strata per square foot of area as about 250 tons, and this is far too small to effect the consolidation necessary. In a set of Strata 10,000 feet thick, the superincumbent weight on the lowest bed would be about $5\frac{1}{2}$ tons per square inch—790 tons per square foot—still too little to do the necessary consolidation. The pressure must have been very great, and we can only imagine how great, and in the imagining, we can be led into an error that may be greater than the assumption.

Passing to the Heat involved in the Metamorphosis. The heat factor is evidently both part of the internal heat of the Earth, and also the heat resulting from Chemical combination. One might suggest that the temperature was below that of molten matter, and probably bears a relation to the temperature of the crust of the Earth, corresponding to the depth at which the metamorphosis took place, and taken as an increase of 1° F. for every 60 feet of depth, only requires a depth of 10,000 feet to be at the temperature of boiling water 212° Fah. That there was Heat, and great Heat is undoubtedly true, and allowing it to be so, we are brought face to face with one of the most marvellous provisions made by nature to attain its ends. I have referred to the fact that each layer, or seam of coal is found lying on the under-clay, and covered by a layer of shale. Without this provision of an impervious covering the gases generated by the mass of decaying and consolidating mass of vegetable matter, when subjected to the great heat, would have been dissipated, and the coal would have more resembled coke, and those properties ot coal that make it so valuable would have been lost to us.

Let us look at the extent of the World's Coal Fields. To do this properly we must do it from two main points: the actually known coal areas, and the estimated areas; and again subdivide the actually known areas into the workable, and the unworkable—at least, now called unworkable, in the absence of knowledge as to how to work the seams at their great depth, but undoubtedly ways and means will be forthcoming if the necessity should arise, to work them, as "Necessity has ever been the Mother of Invention." I do not propose to take the localities individually, it would take too long and be tedious to the point of losing interest, but I propose giving a little time to our own country.

The Royal Commission appointed in 1866 to enquire into, and report upon, the probable time during which the supplies of great Britain would last, issued its report in 1871, and a period of 1,273 years was assigned as the period during which the coal would last, at the then existing rate of consumption. The quantity of workable coal within a depth of 4,000 feet, and contained in seams of not less than 12 in. thick, was estimated to be 90,207 million of tons, or including that at greater depth, 146,480 million of tons.

Since that date, 1871, there has, however, been a steady annual increase in the amount of coal consumed, and subsequent estimates go to show that the supplies cannot last for more than 250 years, or taking into consideration a possible decrease in the consumption, 350 years. It is but fair to state that other estimates have been made which have materially differed from that of the Royal Commission. Where one estimate more than doubled that of the Royal Commission, that of Sir Wm. Armstrong in 1863 gave it as 212 years and Professor Jevons speaking in 1875 concerning Armstrong's estimate, observed "that the annual increase in the amount used, which was allowed for in the estimate, had so greatly itself increased that the 212 years must be considerably reduced." Sir William Ramsay stated in his Presidential Address to the Royal Association, 1911, that "The coalfields of England would be exhausted, at the present increasing rate of using coal, in 175 years," but his estimate of the probable life of the English coalfields has been stated by several of the leading authorities on coal to have been far more pessimistic than the facts warrant. Most of the coal mines now working will have been worked out in less than 100 years, and then perhaps the competition brought about by the demand for and the scarcity of coal from the remaining mines will result in the dreaded importation of coal from abroad.

It is estimated that in the 350 years of coal mining previous to 1850 there had been produced in the United Kingdom:—

2,895,885,000 Metric tons of coal
=2,849,174,374 Eng. ,, ,,

In the 30 years (1870-1900) the output was 5,025 million tons, or one-eighth part of the visible supply that existed in 1870.

With this ringing in our ears, is it not a shame that we export coal so readily and in such large quantities?

In the 38 years (1873-1910) 7,120,810,000 tons of coal were raised, and of this amount 1,660,539,000 tons, or more than 23 per cent. of the total production, were shipped abroad.

In 1890 G. G. Chisholm, M.A., F.R.G.S., in a paper read before the Royal Statistical Society, stated that: "If the same rates of increase as have been found for the period 1880 to 1887 in the United Kingdom, Germany, and the United States were continued in the future indefinitely, the total amount of the production in the United States and Germany would in no long time overtake that of the United Kingdom."

He further stated that he estimated the production of Coal of the three chief producing countries in 1928 as follows:—

	English tons.	Metric tons.
United Kingdom ...	326,034,000	331,380,000
United States ...	2,209,090,000	2,245,306,800
Germany	329,114,000	334,509,640

In the 10 years, 1876 to 1885, the Coal Output of the United Kingdom was 294,827,000 tons, which was only a little more than in the ONE year 1910.

One can scarcely thoroughly appreciate the enormous amount of coal that is brought to the surface annually, and the only wonder is there are any supplies left at all. The Great Pyramid, which is said by Herodotus to have been 20 years in building, and took 100,000 men to build, contains 3,394,307 cubic yards of stone.

Assuming that one ton of coal could be squeezed into one cubic yard, the coal raised in Great Britain in 1910 would contain 264,433,028 cubic yards.

The diagram drawn to scale will thus show it clearer:—

Great Pyramid: Base 764 feet, Height 464 feet.
Coal ,, ,, 3,429 ,, ,, 1,821 ,,

There is over 79 times the cubical contents in the Pyramid of Coal than in the contents of the Great Pyramid, and the weight of Coal raised in that year (1910) is roughly 38 times greater than the calculated weight of the Great Pyramid.

Whilst on the subject of the supplies of Coal, I think I may give you the following figures contributed by M. Ed. Loze, the author of one of the many contributions on the Coal Question.

He has published the following table giving an estimate of the Coal Areas of the World.

	Area in Sq. Miles.
China	over 250,000
United States	200,000
Canada (E. of Rocky Mts.) ...	65,000
British India	35,488
New South Wales	24,000
European Russia	20,000
United Kingdom	12,352
Spain	5,498
Japan	4,778
France	2,079
Austria Hungary	1,789
Germany	1,769
Belgium	509

No mention is made here of the coal fields of New Zealand, Victoria, South Africa and Tasmania, as also many other countries in which coal is found; speaking generally, coal of a kind has been found in every known country of the World. The table shows that coal is distributed through all the Continents, but with much irregularity. Coal measures are also found in the Malayan Archipelago, Sumatra, Borneo, and at Sandy Point Straits of Magellan. In Peru the true coal seams are found on the higher ground of the Andes, usually more than 10,000 feet above sea level, and are practically inaccessible.

Last session the Institute was favoured with a lecture by Mr. Edward Cope, the leader of the present British Antarctic Expedition, and it brings to our minds the fact that during the late Capt. Scott's journeying in the Antarctic regions, he discovered coal seams in those regions. When we now read of the terrible cold experienced in those regions, it is hard to bring to our minds the fact that at some period in the Life of our World those regions basked in a climate comparable with that we now call Tropical, to allow of the immense arboreal growth necessary to the formation of the coal seams. But we are most concerned with the coal fields of the United Kingdom.

The skeleton map will show you how the fields are here situated. I cannot give you individually, statistics of the many coal fields of the United Kingdom, but in passing will mention one or two. The richest coal measures in Great Britain are those of South Wales, they are 8,000 feet in thickness, and yet the aggregate of the many coal seams running through them is only 200 feet or 1/40th of the whole. In the coal field of Midlothian, the seams of coal vary between 2 ft. and 5 ft. in thickness. One of the seams is known as "the great seam," and yet in spite of its name it only attains a thickness of from 8 ft. to 10 ft. in thickness. This will show it is not all comfort to be a miner and get coal. Quite close at home we hear of the Kentish Coal Field, and if the statements of Chairmen of Directors at Annual Meetings of Railway Companies are to be evidenced, we had it stated at one Annual Meeting of the London Chatham and Dover Railway Co., that the General Manager of the line was then busily engaged in arranging for the carriage of the coal from the Snowdon Colliery.

To find really big seams of coal, we must, so far, go out of Great Britain. In Central France there are seams of 30 ft. to 70 ft. in thickness, whilst one seam at Creusot runs locally to a thickness varying between 40 ft. and 130 ft. In the United States there are many seams 29 ft. and 30 ft. thick and many miles in extent of area.

We may retrace our steps for a little, and note the uses of coal at an early period. The ancient world did not know of coal, and had no use for it. About 2,000 years ago the Britons knew the use of coal, and the Romans learned it from them. The Anglo-Saxons used it for domestic purposes, and England appears to be the first country in which it is unmistakably mentioned in writing, the "Saxon Chronicle" being the recording manuscript. England, too, holds the historical record of being the first to work the mineral—a Charter granted in 1259 by Henry III. to the inhabitants of Newcastle to dig coal in their castle fields; but for hundreds of years after that the use of coal was regarded, in London at any rate, as a superfluity, an offence, and a danger to the public health, to be prohibited when Parliament was sitting, and taxed at all times. The tax on coal, which had been a prolific source of revenue under the Stuarts, was remitted in the reign of William III. The explanation of this opposition to the use of coal is, that there was no need of coal in a country leading a simple life with plenty of wood at hand, and no large towns. Why should men with toil and danger dig coal from the dark depths of the Earth when with less labour they could fell a tree?

Now in 1910 there were 1,027,539 persons employed in Coal Mining in the United Kingdom, and the value of the coal produced was £108,378,000. The quantity of coal exported was 84,542,000 tons, leaving 179,891,000 tons for home consumption.

But we must leave this part of my paper and hasten along to another side of the question, and examine the contents of the box. First let me show you a Genealogical Tree Chart of the Parent Coal.

So far we have only dealt with coal in its making by the Marvellous Magician "Nature," let us now see what another body of people—Analytical Chemists—who almost like Magicians, have brought to our gaze and for our uses.

Here we have a piece of coal, and here some of the many things we enjoy from it.

First and foremost of course is the illuminating gas we use in our homes.

In 1600, Van Helmont, a Dutchman, prying into the properties of fuels, found that coal "did belch forth a wild spirit or breath," which he forthwith named gas, deriving the word from, as some say, the Dutch or German variant of ghost, or as others will have it, from the German "Gast," meaning yeast.

Fifty years later, Dr. Clayton, a Yorkshire rector, distilled some coal in a retort, and found likewise that it gave off "A wild spirit or breath of such force as to break his glasses." Later, another Reverend Doctor, named Watson, who dabbling in the profane arts and mysteries of chemistry, found that 96 oz. of Newcastle coal weighed only 68 oz. after distillation, and tabulated the leakage with charming simplicity as "Loss of weight."

But Prometheus, unbound and triumphant, appeared in 1792, when Wm. Murdoch, an engineer, lighted his house at Redruth, with gas, and who 10 years afterwards, as the result of numerous experiments which he made with a view to its utilisation, gave a public display at Soho, Birmingham, on the occasion of the Peace of Amiens, 1802. In 1804, F. A. Winzer, a native of Moravia, took out a patent for "An improved oven, stove, or apparatus for the purpose of extracting inflammable air, oil, pitch, tar, and other acids from, and reducing into coke and charcoal, all kinds of fuel."

London received its first instalment of gas in 1807, but it was not, however, till about the year 1820 that its use throughout the country became at all general; St. James' Park was lit with gas in 1821. Accustomed as we are at the present day to our street after street of well lighted thoroughfares, and our well lighted homes, we can scarcely appreciate the fact that the use of gas is comparatively of but recent growth, and that, like the use of coal itself, it has not yet existed a century in public favour. The coal carbonized by gas undertakings (private and municipal) in 1910 was 15,397,783 tons.

Coming to our own midst; in 1911 the Gas, Light and Coke Co., at Beckton, carbonized 1,816,962 tons of coal, making 25,484,985,000 cubic feet of gas; using in addition to the coal mentioned 13,401,101 galls. of oil for carburetted water gas. The great Sir Humphrey Davy, who, when the occasion demanded it, rose to it, and gave to the world "The Miners Safety Lamp," once mockingly asked the Gas Light and Coke Co. if they would like the Dome of St. Paul's for a Gasholder? The then Engineer of the Company, Samuel Clegg, prophetically replied that he hoped one day to see them equal in size; and ere he died this size of gas holder was exceeded, one at Beckton being 785 ft. girth, within which the dome of St. Paul's might be very easily and comfortably contained.

In the early days of coal working it was thought to be wonderful to raise 90 tons of coal in a day from a shallow pit. Now 3,360 tons have been raised in one day at the Cadeby Mine, Doncaster, from a depth of 763 yards.

From a ton of Bituminous Coal may be distilled:—

10,000 cubic feet of Gas.
30 lbs. of Ammonia Liquor.
139 lbs = 12 galls. of Coal Tar.
13 cwt. of Coke.

and we can from a ton of coal extract 30 lbs. of Sulphates, saleable at £12 per ton.

First, we have coal, then comes the five first distillations from coal, Gas, Coal Tar, Ammoniacal Liquor, Coke, and Sulphur, with a little water.

Little need be said about the Coke and the Gas, except to point out that the Sulphuretted Hydrogen in the gas, which must be removed on account of its harmful character, is made to pay part of the cost of production. The amount of Sulphur in Coal is small, about 1 per cent. to 2 per cent.—an average of 35 lbs. per ton. Only about 1/3rd of this reaches the gas purifiers as Sulphuretted Hydrogen, yet so large is the quantity of coal which is treated in the gas works of Great Britain, that in the aggregate the recovered Sulphur amounts to thousands of tons per annum. Another impurity in Coal Gas which has to be removed is the poisonous compound of Hydrocyanic Acid. By suitable chemical methods it is extracted from the crude gas and converted into Potassium Ferrocyanide. From this product it is easy to prepare either Prussian Blue for the manufacture of printing inks, or Potassium Cyanide, which is extensively used in gold extraction and in electro plating.

The objectionable impurity, Hydrocyanic Acid, present in the Crude Coal Gas to the extent of less than one part in 1,000, is converted into useful products.

Now dealing with the Ammoniacal Liquor. The Ammoniacal Liquor which has been passing over during the distillation of the coal is collected and treated to a variety of chemical reactions in order to wrench from it its useful constituents. Ammonia stands in the first rank, and in order to obtain this the liquor is first neutralized by being treated with acids, which converts the principal constituents of the liquor, viz.: Carbonate of Ammonia (smelling salts) into either Sulphate of Ammonia or Chloride of Ammonia (familiarly known as Sal Ammoniac) according as Sulphuric Acid or Hydrochloric Acid is the acid used.

By a further treatment of these with lime or, as is chemically known, oxide of calcium, ammonia is set free, whilst Chloride of Lime, the well known disinfectant, or Sulphate of Lime (Plaster of Paris) is the result.

The residue Sulphur has been noted, and in these days when every available source of wealth is being looked up, it is to be hoped that the conversion of the Sulphur into Sulphuretted Hydrogen, and then into Sulphuric Acid or Oil of Vitriol will be "un fait accompli," and our atmosphere will be spared being longer the receptacle of the unowned and execrated brimstone of millions of fires and furnaces.

Now we come to Tar, and its distillates. The unlovely qualities of this primary bye-product of coal needs no exposition, yet out of this dirty, sticky substance the chemist has evolved all manner of useful and wonderful things. Long after the introduction of Coal Gas the Tar was a nuisance, a disagreeable bye-product, the removal of which involved the manufacturers in considerable expense. The demand for it was exceedingly small, and far short of the quantity made at the gas works. Two men who carried on the distillation of tar in those early days have left it on record that the Gas Company gave them the tar on condition that they removed it at their own expense. The Naptha which these workers got by the distillation was used by

Mr. Mackintosh, of Glasgow, in dissolving indiarubber, for the manufacture of the waterproof material which bears his name. In 1838 a patent was taken out for impregnating or "pickling" wood with heavy oil from coal tar, and this proved an important outlet for the gas-manufacturers' refuse. Wood, such as railway sleepers, telegraph poles, etc., that have to be exposed to the action of water, or moist soil, last much longer if steeped in Creosote Oil. In the process of distillation the tar, after standing in tanks for some time in order that any Ammoniacal Liquor which may be present may rise to the surface and be drawn off, is pumped into large stills, where a moderate amount of heat is applied to it. The result is that some of the most volatile products pass over, and are collected. These first products are known as "first light oils" or "crude coal naptha." After a while the "crude coal naptha" ceases to flow, and the heat is increased. A fresh series of products passes over, known as "medium oils." These in turn cease to flow, when by a further increase of heat, what are known as "heavy oils" finally pass over, and when the last of these, "green grease," as it is called, distils over, Pitch alone is left in the still, and this Pitch amounts to about 60 per cent. of the original Tar. The products thus obtained at the various stages of the process are again subjected to further distillation, and a large variety of oils are obtained.

One of the most important and best known products is that called Benzine, or Benzole; this again is heated with Nitric Acid and gives Nitro-Benzole, a liquid having an odour like bitter almonds, and which is much used by perfumers under the name of "Essence of Mirabane," and in a second way, for the production from this Nitro-Benzole of the far-famed Aniline.

By distillation of the "heavy oils," Carbolic Acid and Commercial Anthracine is produced, and so on with the other distillates.

It was an Englishman who made the discovery on which the whole coal tar industry is founded. In 1856 the late Sir Wm. Perkin, while still a lad of eighteen, discovered that when aniline was oxydised by dichromate of potash, a beautiful purple colouring matter was produced. We now call this "mauve colour." A demand soon arose for this, the first artificial dye, and Perkin, with the assistance of his father and brother, started a small factory for its production at Greenford, near London.

The importance of Perkin's discovery lies in this, that, although Aniline occurs only in traces in Coal Tar it is very easily produced from Benzine.

Benzine is first treated with Nitric Acid, and converted into Nitro-Benzine, and Nitro Benzine when heated with Iron Filings and Hydrochloric Acid is converted into Aniline, which contains the elements Carbon. Hydrogen and Nitrogen, and unites readily with acids to form salts. Perkin's discovery that Aniline was the parent substance of artificial colouring matter meant that there was a new outlet for the Benzine from Coal Tar.

Mauve was only the first of a long series of artificial dyes which chemists have succeeded in building up out of the constituents of Coal Tar. At the present time there are over 180 different shades of artificial dyes made; some of them like Indigo and Alizarine have competed successfully with the natural occurring dye, whilst others do not occur in nature at all, but are of purely laboratory origin, such as Magenta and Bismark Brown.

The extensive dye works in Germany, contrasted with the modest works at Greenford, show the phenomenal growth of the artificial colour industry, and it must ever be a source of regret to us, that the foundation of this huge industry was laid in England, flourished only for about 20 years and then allowed to dwindle down to unworthy proportions. About 1911-1912 the value of the artificial dyes exported from Germany to other countries was over £8,000,000 per annum.

The whole story of how the Aniline and other dyes have been produced from such an uninviting mess as Coal Tar is really marvellous; it is truly a "Romance of Dirt." Coal Tar has been made to yield other valuable products besides colouring matters. "Punch" at one time fell to wonder at the host of things that have their origin in Coal Tar, and delivered himself of the following lines:—

"There's hardly a thing that a man can name, of use or beauty in life's small game, But you can extract in Alembic or jar, From the Physical basis of Black Coal Tar. Oil and ointment and wax and wine, And the lovely colours called Aniline. You can make anything from a salve to a star, If you only know how! from Black Coal Tar."

Anything from a salve to a star is rather a tall order, but the variety of purposes to which the derivatives of Coal Tar are applied is certainly very remarkable: In photographic developers; in the colour of microscopic sections, in patent fuel; in the colour of our butter; in artificial perfumes; in the surgeon's antiseptics; in the latest shade of tie; in the explosives, lyddite and T.N.T. In all these we may detect the trail of the Tar. Among the drugs to which the study of Benzine and its derivatives have led are the well known drugs Antipyrine and Phenacetene and Aspirin.

Whoever wants a local anæsthetic, á hypnotic, or an antiseptic, can have his requirements met by something which has been derived from Coal Tar.

Another example of the unexpected things that have cropped up during the study of Coal Tar products, we have Saccharine. This is prepared from the Hydro-carbon Tolvene, and therefore indirectly from Coal Tar. Its remarkable property is its sweetening power, said to be 300 times as great as that of sugar, and is most valuable to people who suffer from diabetes and who have to avoid ordinary sugar.

Many of these valuable bye-products are made right at our doors. Beckton produces: Anthracene, Benzole, Toluol, Naptha, Green Oils, Napthalene, Pyridine, Black Varnish, Disinfecting Fluids, Carbolic Acid, Nitrate, Liquid, Muriate and Anhydrous Ammonia, Cyanides of Potassium and Sodium, and Prussian Blue.

Enough has been said, I hope, to convince you that the work of " Nature " is really marvellous and also that most valuable substances can be, and are, obtained from the most unlikely sources. If you are optimists, these facts will help to confirm you in your view of life. If you are pessimists, prone to see the unlovely side of things, one does well to remember that there is beauty even in dirty Coal and Black Coal Tar.

On August 4th, 1914, my story had to end at this point; to-day, thanks to the urgent call of necessity, amplified by the Britisher's idea of never giving in without a good honest try:—

What have we now? Here are small samples of British Dyes made in Britain, for Britain, and also may we hope for export to the world at large. May it have freed us for ever from the tentacle clutches of German manufactured Dyes. These samples I am able to show you by the kindness and courtesy of Messrs. The British Dyes, Limited, of Huddersfield; to us living within reachable distance of Greenford, where the late Sir Wm. Perkin laboured so long and so diligently, it must be more than gratifying that such is now the case. We must also feel very pleased that Lady Perkin, still resident in that neighbourhood, has been spared to enjoy the great pleasure which unfortunately was denied to her late husband, viz., to see the Dye Industry revived on a sound basis in our own country. Various charts of colours are for your inspection, and I think you will agree that if we accept the work shown as but in the primary stage only, in the near future absolute success is assured.

In conclusion I have to thank you for your kind attention, and I can only hope that the moments spent with the "Marvellous Magician"—"NATURE"—has been time well spent.

The CHAIRMAN: The beautiful colours shown on the diagrams remind me of a lecture I attended at Dollar Academy about 55 years ago, when we had samples of dyes derived from coal tar placed before us, and we school boys were greatly impressed with the possibilities in connection with industrial enterprise and the study of chemistry with a view to further developments. What has transpired since then is a matter of history, bearing several lessons and showing to us that things that are seen cover much that is unseen if we dig deep enough and look beneath the surface—bearing in mind, however, that others may be also observing. Events of the past few years, with the elements of destruction let loose, have shown our short-sightedness in regard to the subject so well put before us to-night by Mr. Hall—leading us to think of the colours of the flowers and the vegetation of by-gone ages being brought to light for succeeding generations to enjoy. Our time has been well spent this evening, and I am sure we have all derived both pleasure and instruction. May I ask Mr. Sayers to express our thanks?

Mr. W. BROOKS SAYERS: I am pleased to rise and propose a vote of thanks to the lecturer. He has carried our minds into an atmosphere of thought and contemplation regarding what is below us in the world. I have been in several coal pits, especially in Scotland, where travelling along for miles has to be done in a stooping posture, but the miners become so expert that they can run along the passage ways with heads down. The subject which called me down below was the electrification of the mines for lighting and working plant. I hope to devote an evening, January 11th, to a view of electricity which will interest you, under the title "Electronomy." I should like to ask Mr. Hall whether he considers the earth has been enlarged by the addition of layers of vegetable growth and meteoric material which have been, and are still being rained upon its surface and pressed down.

Mr. WM. McLAREN: I have pleasure in seconding the vote of thanks to Mr. Hall for the treat he has given us. The subject may not be strictly on engineering, but it has an important bearing on it and we have been greatly interested in the lecture.

Mr. Hall: Referring to the matters which were revealed after 1914 in connection with coal and its by-products, there are several large German colour factories, the Badische Anilin und Soda Fabrib, Ludwigshafen am Rhein, is the largest chemical factory in the world, employing 7,500 workmen, 197 university trained chemists, 95 engineers and 709 clerks (1906). F. Bayer and Co., in Elberfeld aud Leverkusen, is almost as large. Value of Coal Tar colours manufactured in 1910 equalled £20,000,000; and three quarters, or £15,000,000, of this value was manufactured in Germany.

In reply to Mr. Sayers I do not think the size of the world has been increased; the material has been shifted from one quarter to another. We cannot get something from nothing.

I thank you for the vote of thanks; the time spent in preparing for to-night was in the hope that you would be interested, and I am well repaid by the knowledge that you have enjoyed the evening.

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Books Presented to the Library.

Automobile Steel Research Report, 1920. — The Committee, which has produced this valuable Report, contains many names which are household words, and a more representative and authoritative body could hardly have been brought together. The results published are of course, of the first importance to Automobile Engineers and allied industries, and the Report marks a notable advance along the path of metallurgical investigation and will be of the greatest value in furthering progress both in design and in manufacture.

Marine Engineers' Hand-Book. Sterling. *McGraw Hill Book Co.*—This comprehensive volume, of American editorship, follows the lines of the familiar Molesworth, and is a repository of information on a multitude of engineering subjects. It will be found a useful book for reference by Marine Engineers as it deals essentially with the marine phase of engineering.

Malleable Cast Iron. Parsons. *Constable and Co.*—An opportune and useful work on a subject which is "terra incognita" to engineers generally. The book will be most useful to manufacturers, dealing as it does with manufacturing processes, but the information contained in this well written little volume will be of value to all engineers, and much that was dark will be made clear.

General Design of Warship. N. Hovgaard. *E. and F. N. Spon.*—The author has endeavoured to present, in this one volume, a general view of the modern idea of warship design, based upon a long experience. Within the limits set down the work is very comprehensive, but as the subject of machinery installations is not dealt with the book is of value principally to naval architects. Marine and Naval Engineers, however, who are interested in this important subject, will find the work of considerable value, and the subjects are well arranged.

Things a Sailor Needs to Know. Sir D. Wilson Barker. *C. Griffin and Co.*—A collection of matters of interest to seafarers generally, including technical and historical chapters, profusely illustrated, many of the illustrations being from photographs. Much of the subject matter will not be new to experienced maritime officers, but a considerable amount of new matter is to be found in the book. The author includes a few chapters on machinery amongst the "Things a Sailor needs to know," which may be of interest to those not already acquainted with the subject.

Election of Members.

Members elected at the meeting of the Council held on 5th October, 1920.

Members.

Maurice Auché, 33, Quai de France, Rouen.
Lionel Theodore Copp, 26, Belmont Road, Southampton.
Malcolm Cumming, 6, Thread Street, Paisley.
Charles Dring, 14, St. Andrew's Terrace, Sunderland.
Stuart Dundas, 287, Portswood Road, Southampton
Harry Joseph Stanton Ferry, 50, rue du Dock, Havre.
Herbert Ernest Gearing, "Denchworth," Solomon's Road, Cape Town.
James Gilchrist, International Dock, Shanghai, China.
Archibald Hogg, St. Helen's, 69, Western Road, Romford.
William Davidson Love, 326, Hawkshill, Dundee.
James Morton, The Atlantic Engine Co., Ltd., Atlantic Works, Wishaw, Scotland.
Frederick Ernest Rebbeck, Queen's Island, Belfast.

Paul Rossignol, 50, rue du Dock, Le Havre.
William Scott, Neva, Poplar Avenue, Great Grosby, Liverpool.
Robert Sinclair, 37, Wellesley Road, Ilford, E.
John Revelyn Cecyl Welch, c/o Eagle Oil Transport Co., Ltd., 16, Finsbury Circus, E.C.
Herbert Simmond Whitburn, 15, Harrington Street, Liverpool.
Alexander Andrew Wilson, B.I. Engineers' Club, Calcutta.

Companion.

Frederick Roger Williams, 47, Fenchurch Street, E.C.3.

Associate-Members.

Harold Baldwin Lomas, c/oMessrs. Beliard, Crighton & Co., 50, rue du Dock, Le Havre.
Robert Henry Wright, Greenhill House, Kilpike, Bambridge, Co. Down.

Graduate.

Arthur Rutherford, 7, Ryehill Terrace, Leith, Scotland.

Student-Graduates.

George William Oman, 10, Quatre Bras, Hexham-on-Tyne.
John Richard Orde, 132, Park Road, Newcastle-on-Tyne.

Transfer from Associate to Member.

Henry Rue, 116, Fenchurch Street, E.C.3.