Motor Spirit from Coal

By John L. Strevens and Arthur C. Cross

THE report of the Falmouth Committee has disappointed that large section of public opinion which hoped that motor spirit might be produced from coal in sufficient quantities to render Great Britain independent of foreign supplies, either in peace or in war. On the other hand, the report recognizes the immense amount of scientific activity that is being expended on the subject, and it is therefore opportune to consider the position as it is to-day.

Apart from the three branches of the carbonizing industry—gas, coking and low temperature—all of which produce a certain amount of spirit as a by-product, there are three commercially proved systems now at work for obtaining motor spirit from coal, (a) hydrogenation, (b) coal-oil distillation and (c) synthesis.

Research work has brought one of the authors (J. L. S.) into intimate contact with all these processes. He was in Germany in the early days of hydrogenation developments studying the subject in conjunction with the Dye Trust and Dr. Bergius, and supervised research work in this connexion at the Kaiser Wilhelm Institute. During the past two years he has enjoyed welcome entry to the plant, where he has observed the work carried on by the Synthesis group under Dr. Martin, whose immense industry at Oberhausen may be classed as one of the wonders of the modern technical world, and he is one of the technical advisers to the British group who have developed the Cannock process of coal-oil distillation and now have plants at Tipton and Erith.

It is estimated that since Dr. Bergius's original discovery, between £20,000,000 and £30,000,000 has been spent upon hydrogenation, which in Great Britain has culminated in the plant of Imperial Chemical Industries, Ltd., at Billingham. About £10,000,000 has been spent on synthesis since its inception and approximately £1,000,000 on coal-oil distillation processes.

HYDROGENATION

Hydrogenation of coal and oil was first developed in Germany by Dr. F. Bergius and brought to Great Britain by the energy and foresight of the late Lord Melchett some twenty-five years ago. The process as operated to-day is the outcome of the pooling of all the patents and technical information acquired by international chemists and oil technologists in Great Britain, Germany and America, through the medium of International Hydrogenation Patents, Ltd. The part played by the coal

industry in this development has been negligible, a fact which the industry will probably regret in time to come.

In the hydrogenation process a paste of coal and coal-oil is submitted to the intense action of hydrogen under high pressure (275 atmospheres at present at Billingham, though pressures up to 350 atmospheres are contemplated in future plants) in the presence of catalysts of the tin or molybdenum series, whereby partial liquefaction and reduction of the coal substance takes place and corresponding changes occur in the associated coal-oil. At the temperatures employed, simultaneous 'cracking' of the liquid constituents takes place and the ultimate result is the production of motor spirit and gas on one hand and an intractable residue of ash, catalyst, unconverted coal substance and heavy oil on the other.

Hydrogenation requires expensive plant of great strength and complexity to withstand the enormous pressure developed and the intensive action of the processed materials on the equipment. Once hydrogenation is effected, the rest of the plant, dealing with the hydrogenated and cracked oil products, is analogous to that of modern oil refineries.

Apart from the enormous capital cost of the plant, the complicated technique and working of the process—requiring as it does very large additional quantities of coal for power, hydrogen, steam and ancillary purposes—places a cost burden on the venture which is reflected in the very high production figure for the motor spirit obtained.

In 1936, 100,000 tons of coal were processed by hydrogenation at Billingham, and 325,000 tons of coal were utilized in the processing as well as 20,000,000 gallons of creosote and coal-oils. The production of 33,300,000 gallons of motor spirit was equivalent to 60 gallons for every ton of coal and oil utilized.

Although the progress of hydrogenation applied to bituminous coal and coal-oil mixtures has been a brilliant technical achievement, in Great Britain where the raw materials available are much more difficult to treat and much more expensive than they are in Germany, it seems unlikely that it can ever become an economic proposition, even with the excise discrimination intended for the express purpose of encouraging its development.

Any new hydrogenation plant in Great Britain would, according to the Falmouth Committee report, have to be designed to use coal only, as supplies of creosote or low-temperature tar are not available in sufficient quantities to provide for

another mixed coal and tar plant, and from an economic point of view it would have to be of a minimum capacity of 150,000 tons of petrol, such plant estimated to cost £8,000,000.

The only by-products of note obtained in the hydrogenation process are the propane-butane gases, which are marketed in the form of compressed gas for household and industrial use in isolated locations; for example, Calor Gas.

COAL-OIL DISTILLATION

Coal-oil distillation is an entirely British process, organized and financed by W. B. Mitford and a group of colleagues. Eight years have been spent in bringing it to commercial completion. For the past two years much of the work has been done with the co-operation of Universal Oil Products, of Chicago, the well-known American oil cracking authority.

Coal-oil distillation *cum* cracking requires as its raw material a mixture of coal and coal-oil. In the coal-oil distillation plant of the National Coke and Oil Co. this mixture is converted into a coal-oil distillate which, because of changes brought about by its processing, is 'upgraded' into the class of naturally occurring oils amenable to the normal cracking operation. As a result this 'upgraded' distillate refines in a similar way to a medium quality petroleum, yielding a large percentage of high-grade motor spirit. Olefinic gases are also produced, from which further quantities of aviation and polymer spirits are obtainable.

This particular type of coal-oil treatment lends itself to development in widely scattered units, and is only limited by the availability of the coal-oil with which the coal needs to be pasted. If, according to a precedent already established, crude petroleum or its products are used in association with this coal-oil, then in the event of tax discrimination being exercised in favour of motor spirit produced from coal by this means, the possibilities of coal-oil distillation are limited only by the availability of such oils.

Why, it may be asked, is the oil from coal under this process changed into the character of a natural petroleum? This phenomenon has been discussed in scientific circles in the United States, Germany and Great Britain. The probable explanation is that the primary oil constituents of the coal have been 'soaked out' by the associated coal-oil and the deleterious material removed in the processing treatment. The coal-oil distillate 'upgraded' stock yields 43 per cent motor spirit when treated in a modern cracking plant. Thus by this process there has been obtained from coal and coal products (creosote, etc.) an oil stock that is, so far as motor spirit production is concerned, akin or similar to many natural crude petroleum. For the treatment of

our huge supplies of suitable coal this development should prove eminently successful.

A standard unit for a process of this description consists of a coal-oil treatment plant having a daily throughput of 400 tons of 'paste' (50 per cent coal and 50 per cent oil), and a refinery with a capacity of 1,000 barrels of dephenolated 'upgraded' oil stock per day.

On the basis of a yield of 78 gallons of motor spirit per ton of stock treated, such a unit would produce 5,000,000 gallons of high octane product per annum. This yield is guaranteed by Universal Oil Products after testing the stock produced.

No account of coal oil distillation would be complete without reference to the smokeless fuel residuum, phenols, and rich gaseous by-products derived from the process.

The smokeless fuel is, on test, superior in every way to that obtained by ordinary dry methods of coal treatment. Apparently a proportion of oil absorbed in the coke residue imparts valuable properties which are reflected in its higher calorific value, complete combustibility, intense reactivity and high radiant heat value.

The phenols are equal to those produced from high-temperature coal tar, whilst the gas is rich in those higher hydrocarbons, making it particularly suitable for industrial metallurgical operations and as a motor transport fuel when compressed into portable cylinders.

SYNTHESIS

Synthesis, or coal-gas treatment, is essentially a German development which has taken fifteen years to come to commercial practicability. It is based on experiments conducted over a number of years by Prof. F. Fischer and Dr. Tropsch, of the Kaiser Wilhelm Institute. This process forms part of the Four-Year-Plan now being carried out in Germany.

The synthetic processes are based on the well-known fact that oxide of carbon can be hydrogenated at normal pressures in the presence of catalysts of the eighth group of the periodic classification of elements to form a mixture of gaseous, liquid and solid hydrocarbons analogous to crude petroleum. The initial gases can be prepared in various ways from all types of carbonaceous material such as coal and coke, or from oil and gaseous hydrocarbons. Once a mixture of carbon monoxide and hydrogen in predetermined quantities (usually one part carbon monoxide to two parts of hydrogen) of the right degree of purity is available, the production of 'synthetic oil' is an open field.

One form of this development which has been brought to a state of almost technical perfection on an extensive commercial scale is operating in Germany under the name of the "Fischer" process,

but only small-scale experiments along similar lines have so far been carried out in Great Britain.

The synthetic products of the Fischer process consist of 9–10 per cent of gaseous hydrocarbons, 60 per cent 'straight' open-chain paraffinic motor spirit, 28 per cent high-grade Diesel oil fraction and 2–3 per cent wax, but slight modification in processing influences these proportions greatly.

COST PER GALLON

No attempt has been made in the Falmouth Committee report to compare the normal costs per gallon of producing motor spirit by the various processes examined. A fair estimate of the cost for the motor spirit produced by hydrogenation would be approximately 11d. per gallon, remembering that in all new plants it is difficult to assess the amortization figure. The octane rating of this spirit is 70 plus.

The outstanding feature of coal-oil distillation *cum* cracking is that from one ton of coal and one ton of coal-oil make-up there is produced 78 gallons of motor spirit. The approximate cost of this spirit, allowing average price for all other products, is 7·2d. per gallon, and the octane rating is 73–74.

A feature of synthesis is that 5½ tons of coal are required for the production of one ton of synthetic oil product. The yield of finished motor spirit is 40–45 gallons per ton of coal, and the cost may be placed at between 10½d. and 1s. 1½d. per imperial gallon. This range in the estimated price is advisable owing to the fact that in Germany the synthetic industry is very closely associated with the benzole industry and it is not easy to determine the net cost of the synthetic motor spirit. The best octane rating of this spirit is 62.

LIMITATIONS OF THE PROCESSES

Each of the processes considered has its peculiar limitations which must be borne in mind in surveying the economic position.

In the case of hydrogenation, the capital cost is enormous. There are definite limitations to the percentage of coal in the coal-oil paste which it is advisable to treat. There are difficulties in the treatment of the residue and the recovery of the catalyst. It may be that the success of the process will ultimately rest upon the finding of an economic method of separating the catalyst from the residue and the means of handling it.

With coal-oil distillation *cum* cracking an important limitation lies in the supplies of creosote or similar coal-oil products at economic prices. In a state of national necessity the major portion of coal-oil produced would doubtless be made available for the preparation of home-produced motor spirit. If in the interests of the coal industry it were felt wise to make available, unhindered by tax, imported natural petroleum, the field for both hydrogenation and coal-oil distillation would be unlimited.

So far as synthesis is concerned, the motor spirit produced is of low octane rating. It is obvious that there would always have to be available 'upgrading' material at an economic price, such as benzole, alcohol, tetra-ethyl lead, iso-octane, etc. The synthetic process may always be limited by the high cost and availability of the necessary catalyst.

ADVANTAGES

The synthetic process is the only one so far developed which produces from coal a Diesel oil of first quality.

The coal-oil distillation process is the only one of the three under review which produces economically a large quantity of smokeless fuel of high radiant heat value and complete combustibility.

The valuable phenols so essential to the nation's needs in times of peace and war can only be obtained from coal distillation processes and the tar industry, and not from hydrogenation or synthesis.

Plants of the Sand Dune and why they Grow There*

By Prof. E. J. Salisbury, F.R.S.

THE vegetation of a sand dune is unique not only because of the rapidity of the changes that it exhibits but also because, from the manner of dune development, the phases present an arrangement in space corresponding to their sequence in time, so that the plant succession can be ascertained with certainty.

* From a Friday evening discourse delivered at the Royal Institution on February 4.

The embryo dune frequently begins around seedlings of either *Agropyron junceum* or *Ammophila arenaria*. Both are characterized by an important reaction to burial by sand, namely, that they are stimulated to grow through to the new surface. The projecting leaves by reducing wind movement not only shelter the surface from erosion but also bring about further deposition. *Agropyron junceum* can grow normally in 1·5 per