alcohol, and acetone, represent the preliminary stages in the formation of the oily substances, not soluble in water, of "synthol" proper. The water-soluble mixture we propose to call "*pro-synthol.*"

Later researches have shown that synthol, heated in an autoclave in the absence of carbon monoxide, and therefore excluding the possibility of its further addition, is by dehydration converted to a large extent into a mixture of hydrocarbons of pronounced petroleum smell. In that reaction the higher alcohols are probably transformed with loss of water into olefines, and further, by the closing of rings, into naphthenes. Synthol thus transformed into petroleum or benzine we propose to name "*synthin.*" The genetic sequence of the building-up of our compound from carbon monoxide would therefore be: pro-synthol, synthol, synthin. The first and second contain oxygen; the third is free of oxygen, or contains, if not entirely converted, less oxygen.

Much further work will be needed before the technical production or manufacture of synthol is so far improved as to reach the economic stage. We believe, in view of the progress we have made in demonstrating its possibility, that a rational method of converting coal—which, if sufficiently bituminous, would first be deprived of its primary tar—by gasification into water gas, and finally into synthol and low-boiling motor fuels, would be of far-reaching importance generally, and particularly for countries which possess coal but no petroleum. The working scheme would be: coal, semi-coke, primary tar, primary benzine and gas; from the semi-coke, water gas, ammonia, and hydrogen sulphide; from the water gas, pro-synthol, synthol, and eventually synthin.

(*s*) INDUSTRIAL APPLICABILITY OF THE SYNTHOL PROCESS

The Haber synthetic ammonia process, as carried out on the very largest scale at Oppau and Merseburg, seems to furnish the best basis for a comparative consideration of the pressures, temperatures and other factors which the industrial application of the synthol process would necessitate. The technical difficulties of the synthol process are, without doubt, smaller than those of the ammonia process, though it appears much more complex in regard to products. The two components of the Haber reaction, nitrogen and hydrogen, yield only one product, ammonia; in the synthol process, three components, carbon, hydrogen and oxygen, may yield perhaps 100 different compounds. The temperatures required are lower by 200°, being 410° instead of 600°, a point of great importance for the construction of the contact tubes. Not only the temperature, but the composition of the gas makes for greater durability of the contact tubes. According to statements in the technical literature, the hydrogen in the Haber process has an undesirable effect on the steel of the tube, in that it dissolves carbon from the steel in the form of methane and combines with the soft iron thus produced to a brittle hydrogen–iron alloy, of low tensile strength. Special measures had to be devised to circumvent this difficulty. Whether it is really hydrogen, and hydrogen alone, which causes the brittleness of the steel in the Haber process, remains to be seen. It is conceivable, though this has not been suggested in the literature, so far as I am aware, that the brittleness of the steel is due to ammonia itself and to the formation of iron nitride. The best temperature for the formation of iron nitride (which in a pure state has the appearance of white firebrick) from ammonia and iron lies between 450° and 475°. At atmospheric pressure ammonia acts even above 475° on iron with formation of nitride, and it is therefore possible that the reaction at high pressure still takes place at 600°.

However that may be, nitride formation is out of the question with the gas mixture of the synthol process. The risk of a deleterious action of hydrogen is counteracted by the presence of carbon monoxide which has a carburising action on the steel. This argument is supported by the fact that with water gas at 410° we have never observed our steel tubes to get brittle, though keeping them in use for years. Nor was any hardening effect found in reboring the tube.

It would thus appear that the construction of apparatus for the synthol process is less difficult than that for the Haber process, since the deposition of carbon in the contact tube has been successfully suppressed, and the pressures are not so high.

Gas Supply.—A suitable gas for synthol manufacture is water gas; producer gas is also applicable, as well as blast-furnace gas or carbon monoxide, mixed with steam. An excess of hydrogen * being advantageous, it is advisable to add hydrogen or coke-oven gas to water gas; a proper gas mixture may be made directly by steaming in coke-ovens. If it is not desired to mix other gas with water gas, an excess of hydrogen over carbon monoxide may be secured by using a water gas rich in carbon dioxide, and scrubbing out the latter. Another alternative, which is probably preferable, is to admix steam with water gas and catalytically convert some carbon monoxide into hydrogen and carbon dioxide, which latter is washed out; or else part of the water gas may be thus treated, and the residual hydrogen added to another part. The removal of the carbon dioxide may be effected in various ways, the most efficient being washing out with water under pressure.[169]

If gases containing nitrogen, such as ordinary producer gas and blast-furnace gas, are used, higher compression must be applied in order to attain the

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* The advantage lies partly in the prevention of carbon deposits. The chief point is that the gas originally contains as much hydrogen as corresponds to the composition of synthol. If one imagines the elements of water to be split off from the alcohol and ketones in synthol, the ratio of the residual carbon to hydrogen would be 1 C : 2 H. To convert water gas completely into synthol, alcohol and water, it should be so enriched with hydrogen that there are 2 parts of hydrogen to 1 part of carbon, as if the intended reaction were: $CO + 2H_2 \rightleftharpoons CH_2 + H_2O$. Besides, it appears more advantageous that the oxygen of carbon monoxide, which does not enter into the synthol, should form H_2O and not CO_2, as in form of water it can be eliminated by simple condensation between two successive contact tubes.

same absolute pressure of carbon monoxide, as it should have in gas free of nitrogen.

It need hardly be said that for the production of the water gas any solid fuels are utilisable, such as coal, peat, wood, and their carbonising residues.* This fact imparts a certain independence to the synthol process, as it can be carried on where cheap power can be obtained, some kind of fuel being available almost anywhere. Even natural gas is applicable, as it readily yields the necessary hydrogen, carbon monoxide and carbon dioxide.

Since one may start from carbon dioxide instead of carbon monoxide, provided hydrogen be available, yet another variant is to produce hydrogen electrolytically and to extract carbon dioxide from flue gases, or lime-kiln gas, or even from the atmosphere. If an economical method could be developed by which carbon dioxide is washed or frozen out of air, it should be feasible in districts where cheap water power is available, or with some future form of energy, to manufacture synthol after the manner in which Nature has built up fuels using atmospheric carbonic acid as raw material and light as the source of energy.

The Supply of Energy.—Since the formation of synthol liberates energy, in large contact apparatus some heat would probably be required for starting-up but very little for running. Some cheap source of energy must be found for compressing the gases. A small portion of this energy would be recoverable by expansion of the unconsumed gas, but the process should be initiated with such gas mixtures and so conducted that the conversion is fairly complete, leaving little energy to be recovered. In view of the various possibilities of treating the problem, it is purely a question of economics whether the compression energy should be generated in coal-power or in water-power plants, whether coke should be transported to water-power stations or electric energy transmitted to the fuels at their source of origin, or whether finally, what seems the most reasonable course, energy and raw material should be produced in the coal-fields. The compression energy might also be derived from the spare power of large coal-burning power stations during light-load periods. Water gas, accumulated in ordinary gas holders, might be compressed during such periods into high-pressure storage tanks from which the contact plant would be supplied in a continuous process. The discontinuous operation of ordinary water gas plants is a disadvantage. The continuous electric water-gas generators [193] of Stassano may deserve attention in this connection.

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* It is interesting in this connection to compare the hydrogenation of coal with synthol formation. The former succeeds best with geologically young coals and by hydrogenating causes degradation from large to smaller molecules. In the case of synthol, the nature of the fuel is immaterial. As gasification always starts from the carbonising residue, the youngest coal will serve as well as the oldest. Further, synthol is built up by small molecules growing into larger molecules. Thus the low-boiling compounds are first produced and from these the liquid fuels of high boiling range; the latter result only in so far as they are still stable under the conditions of their formation.

CHAPTER V

HYDROCARBONS FROM CARBIDES

There is yet another way for the direct or indirect conversion of coke into liquid hydrocarbons, not depending upon gasification of coke and catalytic treatment of the water gas produced. By thermal processes, carbides can be obtained from coke and suitable oxides or metals, to be subsequently decomposed. Moissan divided the carbides into two groups: (1) Carbides which yield hydrocarbons by decomposition with water, and (2) Carbides which are *not* decomposed by water alone. To the former class belong the carbides of the alkalis, the alkaline earths, of beryllium, aluminium, manganese and uranium, and the carbides of the rare-earth metals.

The carbides of the other metals are not decomposed by water under ordinary conditions, but some yield hydrocarbons when treated with dilute acid. Some of the carbides decomposable by water generate only one kind of hydrocarbon, either acetylene or methane. Other carbides do not evolve a uniform gas, but a mixture of different gaseous hydrocarbons, and, in addition, frequently liquid and solid hydrocarbons. From such carbides free hydrogen and carbon is occasionally separated.

One of the carbides which, decomposed with acids, evolve liquid and solid hydrocarbons, is uranium carbide. Some other less costly carbides yield liquid hydrocarbons; even the iron carbides present in iron and steel do so when treated with acids. Though there is so far no indication of a practical method of producing liquid hydrocarbons from metallic carbides, reference to the theoretical possibilities must be made in the concluding chapter of this book. These possibilities include the production of carbides which directly generate liquid hydrocarbons, and the indirect method of converting acetylene and methane, the gaseous decomposition products of carbides, into liquid hydrocarbons.

(a) CARBIDES WHICH DIRECTLY YIELD LIQUID HYDROCARBONS

Manganese carbide, prepared in the electric furnace from Mn_3O_4, generates with water a gas consisting of methane and hydrogen.[194]

Attempts to prepare a double carbide of calcium and manganese which might yield acetylene, methane, and hydrogen, have been unsuccessful.[195]

By heating powdered manganese metal in a current of methane (not a practical proposition) very high-carbon carbides can be prepared. Dissolved in dilute acid, such carbides containing more than 8 per cent. of carbon leave fatty or paraffin-like hydrocarbons and spongy carbon. Hilpert and Paunescu,[196] who have experimented in this direction, suggest that these respective manganese carbides do not contain single molecules, but polymerised molecules of long carbon-chain structure.

That the dissolution of ordinary iron containing some carbon does not yield pure hydrogen has long been known from the peculiar odour of the gas. It has further been demonstrated that in the decomposition of iron carbide, isolated from steel, more than half of the carbon may occur as gaseous hydrocarbons. These hydrocarbons are partly saturated and partly unsaturated compounds, the latter consisting mainly of butylene.[197] A small quantity of liquid hydrocarbons is always observed, but statements differ as to the presence of free carbon.

Mylius, Foerster, and Schöne [198] found that in the decomposition of iron carbide by acids, 100 volumes of the gas evolved contained a quantity of hydrocarbons equal to 15·3 volumes (calculated as gaseous carbon). Decomposition of iron carbide by steam or superheated water did not yield hydrocarbons but hydrogen, an observation of some importance for technical developments. For commercial purposes decomposition of iron carbides, or highly-carburised iron, only by water or steam, but not by acids, can be considered. All investigations, though differing as to details, indicate that iron carbide on decomposition yields negligible proportions of liquid, and mainly gaseous hydrocarbons. A statement in the literature [199] that the carbon in iron carbide forms predominantly " liquid " products is due to an obvious misprint, " fluid " instead of " volatile " (" flüssige " instead of " flüchtige "), as shown in a later paper by the same authors,[200] which speaks of volatile hydrocarbons as predominating. This statement is in accord with the observations of other workers. According to Hilpert and Dieckmann,[201] there are, in addition to Fe_3C, the carbides Fe_2C and FeC, formed by the action of carbon monoxide upon iron oxide or upon Fe_3C. On dissolving these very stable carbides in hydrochloric acid, large quantities of fatty substances are formed; the gases evolved are chiefly hydrogen and a little methane.

Schenck, Giesen, and Walter [202] have recently published a paper on the decomposition of metallographically well-defined iron and manganese carbide alloys. Determining the hydrocarbons, qualitatively and quantitatively, and establishing a carbon balance between the iron carbide and the products of reaction, they arrive at the figures of Table LXXXVI.

Among the gaseous hydrocarbons propylene and butylene predominate to a striking extent. The liquid hydrocarbons, hexene and octene, are present in minor proportions. The large amount of residual carbon is very curious. When the ferrous chloride solution was continually withdrawn and replaced by fresh acid, the iron carbide was dissolved with complete hydrogenation of the carbon. According to Schenck, deposition of carbon occurs when ferrous chloride is allowed to concentrate in the acid, as then the potential difference between the iron and the iron solution is changed so that the hydrogen liberated has a diminished reducing power.

TABLE LXXXVI

Hydrocarbons.	Alloy 2. Cast iron 2·5% C. Cementite, Perlite.	Alloy 3. Steel 1·7% C. hardened at 1150°. Cementite, Austenite, Martensite.	Alloy 4. Steel 1·7% C. hardened at 780°. Cementite, Martensite.
1. Methane	1·02	3·53	3·19
2. Ethane	0·10	0·50	0·45
3. Ethylene	0·27	0·50	0·47
4. Propylene	7·08	24·37	25·21
5. Butylene	4·00	10·25	9·08
6. Amylene	1·25	3·36	4·20
7. Hexene	1·15	4·37	5·21
8. Octene	0·80	3·02	3·36
9 Carbon	78·04	38·82	42·10
Loss	6·29	11·28	6·73

Another explanation of the appearance of long-chain hydrocarbons assumes the pre-existence of these chains in the iron carbides. Schenck inclines to the view that the hydrocarbons are formed by interaction between nascent carbon and nascent hydrogen.

The study of the conditions under which hydrocarbons, and particularly liquid hydrocarbons, are formed in the decomposition of the iron carbides is undoubtedly of importance; it might indicate the best conditions under which decomposition should be effected. For the present, the yields of liquid hydrocarbons from carbides are too small, and even if they should be capable of considerable improvement, their production would only acquire practical importance if decomposition could be effected by means of steam. In that case, the hydroxide formed might be reconverted into carbide by means of carbon monoxide, and the process might then become a commercial proposition. Those possibilities are, however, remote.

The carbides which give better yields of liquid hydrocarbons are unfortunately very expensive, and will, therefore, be noticed very briefly. Among these are the carbides of cerium, lanthanum, samarium, thorium and uranium. Uranium carbide can be decomposed by water. The gases consist of 15 per cent. of hydrogen, 78 per cent. of methane, 7 per cent. of ethylene and a fraction of 1 per cent. of acetylene; they represent only one-third of the carbon content of the carbide, the other two-thirds remain in the residue as liquid or solid hydrocarbons. By the expense of regenerating uranium carbide from the oxide, and the high cost of uranium minerals themselves, this process is doomed to failure.

(*b*) CARBIDES GIVING HYDROCARBONS WHICH CAN BE CONVERTED INTO LIQUIDS

Calcium carbide, which is the best known of all the carbides and the only one manufactured on a very large scale, yields acetylene on decomposition with water. Pure acetylene is generated by the carbides of the alkali and the alkaline earth metals. Magnesium has been stated to form a second carbide yielding allylene.[203] That acetylene is transformed into tarry products containing benzene, when passed through tubes at red heat, was shown by Berthelot.[204] The reaction according to the equation $3C_2H_2 = C_6H_6$ looks very simple. In reality the reaction does not proceed either exclusively or predominantly in this sense. In order to suppress the strong soot formation which accompanies it, Richard Meyer [205] diluted acetylene with an equal volume of hydrogen and effected decomposition in electrically and uniformly heated tubes at a temperature between 640° and 650°. Much carbon was still deposited; the tar represented not more than 60 per cent., and the benzene 12 per cent. of the weight of acetylene. The conversion of acetylene into benzene gives, therefore, a decidedly low yield. Other experiments [206] in this direction, aiming at more favourable conditions, were not more successful, and, for the present, calcium carbide cannot be considered a suitable raw material for the economical production of benzene by an indirect method.

This opinion is little affected by the experiment of Tiede,[207] who, working at 610° and taking particular care to keep the temperature constant, obtained about 40 per cent. of oily products from acetylene. A good catalyst was not discovered, and the same results were obtained without catalysts. About 50 per cent. of the oil fractions boiled between 50° and 150°, and 15 per cent. between 150° and 200°. Referred to the acetylene consumed, the results are not much better than those of Richard Meyer.

More recently N. Zelinsky [208] has shown that the polymerisation of acetylene to benzene takes place with a much better yield if the acetylene, adsorbed by activated carbon and thus highly condensed, is exposed to a temperature of about 600°. He then succeeded in obtaining 70 to 74 per cent. by weight of the acetylene as a light tar, half of which boiled below 150° and contained about 35 per cent. of pure benzene. Referred to the acetylene used, the yield of crude benzol, boiling below 150°, would be 35 to 37 per cent., and that of pure benzene 25 per cent. These yields are approximately twice as high as those of Meyer, but still represent only a quarter of the theoretical. The higher-boiling products contain toluene, xylene, styrene, indene, naphthalene, fluorene, and anthracene. One hundred parts of acetylene tar yielded the fractions: 20° to 150°, 45 per cent.; 150° to 250°, 14 per cent.; above 250°, 29 per cent.; residue, 12 per cent.

The amount of liquid motor fuel would, in the most favourable case, be

$45 + 14 = 59$ per cent. of the tar, or about 40 per cent. of the weight of acetylene used.

More favourable yields have been realised by the action of the silent electric discharge,[209] which polymerises acetylene quantitatively to an oily substance. But this oil is exceedingly unstable; exposed to the air it absorbs oxygen avidly. Out of contact with air, the oil becomes progressively more viscid, and after a few days it forms a very hard brittle mass. For practical purposes this mode of preparing oil from acetylene may, therefore, be excluded.

Another possibility of producing liquid hydrocarbons from acetylene was described by Sabatier.[164]

If acetylene mixed with double its volume of hydrogen is passed over finely divided reduced nickel, some carbon is deposited, the mass heats spontaneously, and gaseous and some liquid saturated hydrocarbons are produced. With a smaller excess of hydrogen more liquid hydrocarbons are obtained, whilst the spontaneous heating of the nickel is more intense. The hydrocarbons obtained in the latter case are partly hydroaromatic and partly aromatic. This hydrogenation of acetylene, according to Sabatier, does not seem promising for the practical manufacture of liquid fuels.

There remains, finally, the possibility of utilising the carbides which generate methane. So far, nothing is known in regard to the transformation of methane with loss of hydrogen into liquid hydrocarbons, though the problem, given suitable conditions, cannot be dismissed as impossible. If such a method could be found, it would appear to be more advantageous to prepare the methane by the reduction of carbon monoxide than from carbide. Methane from coke-oven gas and the fire damp from coal mines, and above all of natural gas, could then be pressed into service.

Reviewing the practical possibilities of obtaining liquid fuels by way of carbides, the conclusion forces itself upon one's mind that the future of this field of research remains as yet entirely obscure.

Of the various methods for the conversion of coal into oil which have been examined in this book, primary tar production, followed by rational working-up of the tars, and combined with preparation of synthol from semi-coke and water gas, would appear to be the most promising. I do not wish to conclude without pointing out that I have purposely limited myself to describing the more recent processes in course of development, or capable of development. I have left in the background the older and the well-tried methods of the last decades; more novel, Utopian proposals I have considered myself justified in excluding.

APPENDIX (EDITOR'S NOTES)

(a) *Recent Developments in Low-Temperature Carbonisation.*

THE technique of low-temperature carbonisation has made considerable progress in recent years, particularly in Great Britain. The exaggerated claims for individual types of plant put forward by some of those exploiting inventions in this branch make an unbiased technical judgment somewhat difficult. In view of the national importance of the problem, the Fuel Research Board has been empowered by the Government to make tests at the public expense of plants for the low-temperature carbonisation of coal, with the object of placing in the hands of those interested accurate technical data, but without pronouncing on their commercial possibilities.

The first plant submitted to test under this scheme was the Parker plant, installed at the Barugh (Barnsley) works of Low-Temperature Carbonisation, Ltd. The results obtained and published by the Department of Scientific and Industrial Research [210] may be taken as authoritative, and an abstract of the report is given below. Additional interest is lent to this test in that the plant examined is designed practically on the lines of that originally built by Thomas Parker, the pioneer of low-temperature carbonisation.

Another process which has reached the commercial stage is that of R. Maclaurin. Although this has not yet been submitted to test by the Fuel Research Board, the fact that a large plant under Maclaurin's patents has been erected at Dalmarnock Gas Works by Messrs. Blair Campbell and McLean, Ltd., for the City Corporation of Glasgow justifies the inclusion of its description in these notes.

Parker Plant.—The general lay-out of the plant is shown diagrammatically in the drawing (Fig. 73). The pipe lines and recovery plant had not been specially constructed to suit the setting under examination, but had been altered and adapted from the services of a former plant. The setting not in use during the test is shown dotted.

Each setting consists of a battery of 32 retorts, arranged as shown, the off-take pipe of each leading to a hydraulic main running along the side of the setting.

A retort consists essentially of an iron casting in one piece containing 12 vertical tubes arranged as shown in the drawing. These tubes taper from 5½ inches diameter at the bottom to 4½ inches diameter at the top, and are 9 feet in length. A special iron swing door, operated by a wheel on the charging platform, closes the bottom of the retort tubes and separates them from a cooling chamber. This chamber is built of brick and one chamber is provided for each pair of retorts. A gas-tight door allows access to this chamber for discharging coke. While the coke is cooling in the chamber any gas liberated is drawn off into a secondary main below the hydraulic main. The gas leaving the system passes through a governor to a condenser (air-

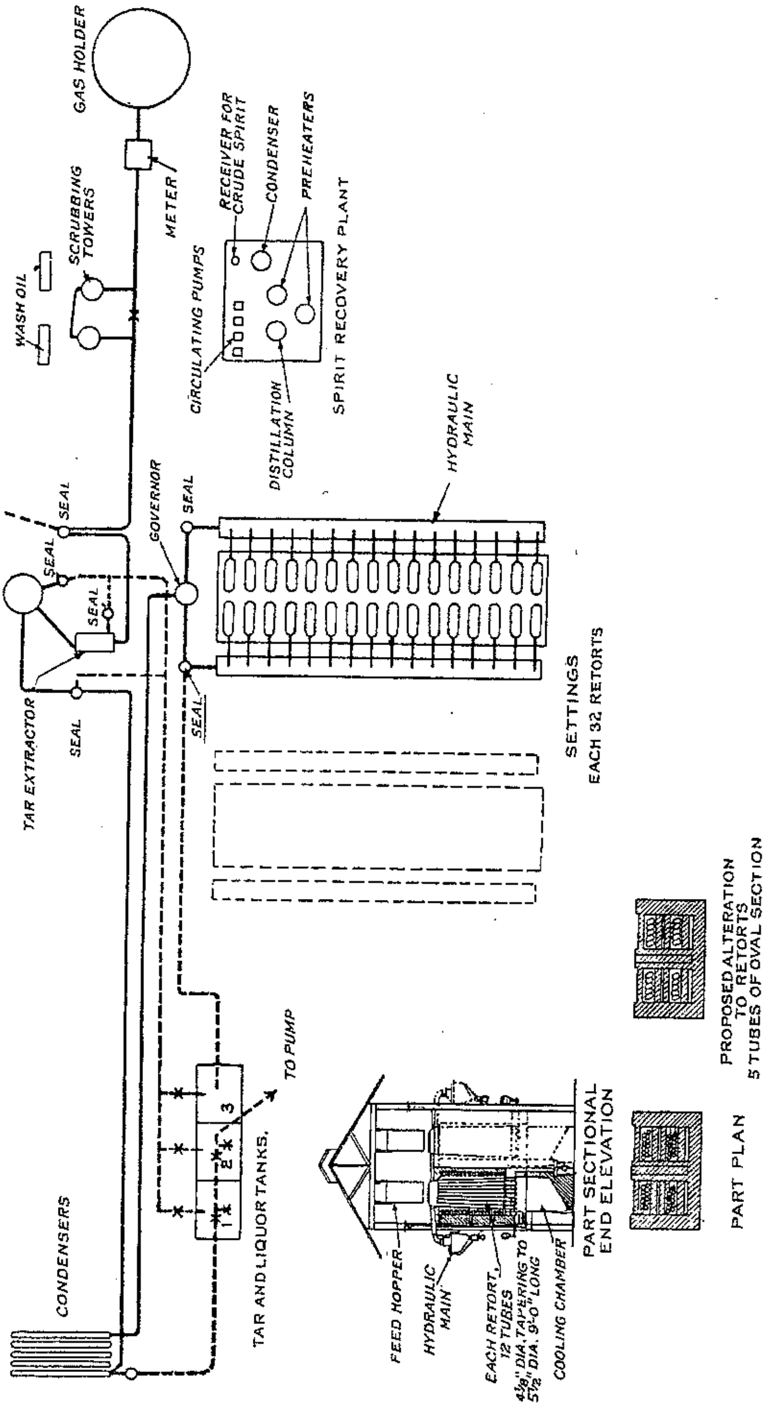
GAS HOLDER
METER
SCRUBBING TOWERS
WASH OIL
RECEIVER FOR CRUDE SPIRIT
CONDENSER
PREHEATERS
CIRCULATING PUMPS
DISTILLATION COLUMN
SPIRIT RECOVERY PLANT
HYDRAULIC MAIN
SEAL
SEAL
SEAL
SEAL
SEAL
SEAL
GOVERNOR
EXHAUSTER
TAR EXTRACTOR
SETTINGS
EACH 32 RETORTS
PROPOSED ALTERATION TO RETORTS 5 TUBES OF OVAL SECTION
PART PLAN
PART SECTIONAL END ELEVATION
FEED HOPPER
HYDRAULIC MAIN
EACH RETORT, 12 TUBES 4⅜" DIA. TAPERING TO 5½" DIA. 9'-0" LONG
COOLING CHAMBER
TO PUMP
1
2
3
TAR AND LIQUOR TANKS.
CONDENSERS

FIG. 73.

cooled), an exhauster, a tar extractor, an oil-washing plant, a rotary gas-meter and finally to a holder (of 25,000 cubic feet capacity). In this holder it is mixed with producer gas and the mixture used as a fuel gas to heat the settings. Two main seals are provided, one at the end of each hydraulic main, and from these the tar and liquor flow to a collecting tank. The tar and liquor from the condenser and from the seals below the exhauster and tar extractor flow to a different collecting tank.

A weight balance was prepared and found to show a loss of 0·48 per cent. This, in conjunction with the thermal balance loss of 5·2 per cent., may be regarded as very satisfactory.

The yields of products per ton of coal were as follows:—

Coke	13·92 cwts.
Gas	5,620 cu. ft. or 39·6 therms
Tar	18·62 gallons
Liquor	26·00 ,,
Crude spirit	1·78 ,,
Ammonium sulphate	13·55 lbs.

The coke or smokeless fuel produced was of a very suitable size (1 to 3 inch pieces). It was not friable, and contained only 4·6 per cent. of breeze below ½ inch. Analysis of this coke showed that it contained only 4 per cent. of volatile matter. When burnt in a household grate it was readily ignited and gave a good hot fire.

The yield of tar was high, representing 68 per cent. of that obtained in the assay apparatus.[211] On examination this tar proved to be a normal low-temperature tar.

The yield of gas was fairly high and, throughout the test, varied considerably both in volume and in calorific value owing to variations of pressure in the hydraulic main.

The yield of ammonia was also fairly high. The liquor was, however, less than 6 ozs. strength, and it is questionable whether so dilute a liquor would justify recovery.

The crude spirit obtained by scrubbing the coal gas amounted to 1·78 gallons per ton of coal. The refining figures and distillation range of this spirit are given in the report.

Details are given of the working operations, of the labour and power required, and of a variety of noticeable points in the handling of the setting.

The temperature of carbonisation was not uniform throughout the setting, varying from 600° to as high as 800°. Suggestions are made for the improvement of temperature control. The amount of fuel consumed in the setting was excessively high, owing to this high temperature, to insufficient heat insulation and to badly designed combustion chambers. There is no doubt but that the 83·5 therms consumed per hour could be reduced considerably.

Maclaurin's Plant.[212]—This installation consists of a battery of 5 units, each unit being capable of carbonising 20 tons of coal per 24 hours. The general appearance of the producer unit (see Fig. 74) is somewhat like that of a blast furnace, but it is built square and raised from the ground on piers. The height from charging hoppers to discharging chutes is 36 ft., and the internal width at the widest point is 8 ft., tapering upwards and downwards.

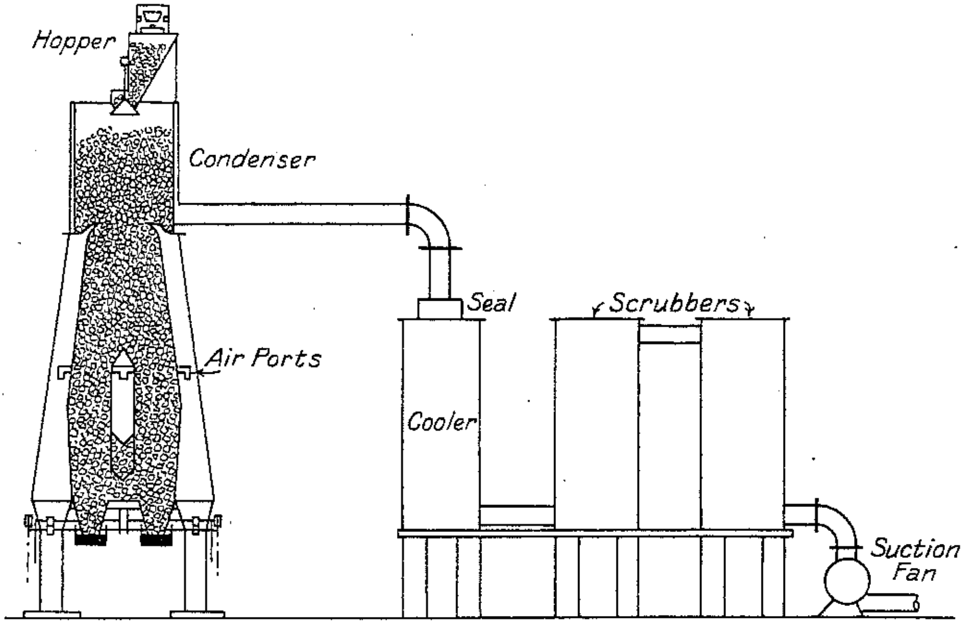

FIG. 74.

A centre wall divides the lower portion of the plant into two chambers of equal size. The air enters through ports in the centre and side walls. The coke after cooling is discharged through chutes at the bottom.

In starting up for the first time the producer is filled with ashes to a little above the air ports. Inspection doors at this point are used for lighting up. Through these doors a quantity of wood is inserted and lighted. When properly ignited, the producer is rapidly filled to the top with coke, the air blast being kept going all the time. When the heat has travelled well up the producer, sufficient ash is discharged to permit a ton of coal being dropped in through the bell. Every hour thereafter a discharge is made and approximately one ton of coal is admitted. After 20 hours the first charge of coal will be approaching the combustion zone, and at from 25 to 30 hours the first coke made from the coal added will be withdrawn.

It has therefore taken 20 hours to raise the coal from 15° to the desired cooking temperature of approximately 700°. The coal descends about one foot and its temperature is raised about 35° per hour. This very gradual increase in temperature is responsible for the production of a coke which is quite different from ordinary gas coke.

The appearance of the coke differs sometimes so little from that of the original coal that it does not seem to have been carbonised at all. Usually, however, the coke is much more open and cellular in structure than the original coal, though its shape has changed very little. The distortion becomes greater the higher the caking index of the coal used. It is hardly correct to term this coke a low-temperature coke, for it has been heated to a temperature well above 600°, and it retains only from 3 to 4 per cent. of volatile matter. It, however, ignites quite readily if the temperature has not been excessive. Maclaurin considers that the ease of ignition is due to the porosity of his coke, and not to the volatile matter remaining in it.

When the temperature is raised beyond a certain degree, a completely different coke is produced. Instead of the black and easily-ignited smokeless fuel, a silvery-grey coke is obtained; its ring when struck is more metallic, its hardness slightly greater and it is not so readily ignited, although the percentage of volatile matter differs so little from the black variety that the ordinary laboratory test fails to distinguish between the two types of coke.

The yield of gas and type of coke produced are interdependent. Black smokeless fuel is produced with a make of gas of between 25,000 and 30,000 cubic feet, and the grey type with a make of over 30,000 cubic feet per ton of coal.

From the Scottish coals tested, which contained from 6 to 10 per cent. of moisture, and from 30 to 35 per cent. of volatile matter, about 55 per cent. of smokeless fuel has been obtained.

Before the coke is withdrawn it has to be cooled, and for this purpose steam is blown in at the discharging chutes. The steam first cools the coke and is then itself decomposed into water gas, as it approaches the combustion zone.

In the combustion zone, air at 60° saturated with water vapour maintains the temperature by burning a portion of the carbon of the coke. The hot producer gas made in this zone supplies all the heat necessary for carbonisation. This gas has a calorific value of about 150 B.Th.U. Above the combustion zone there is a zone where the fuel is between 750° and 500°. Above this is the distillation zone, where the coal is giving off tar and gas. The gas liberated has a high calorific value, possibly 700 to 800 B.Th.U., but its volume is relatively small. This gas mixes with the producer and water gas made below, and after passing through the coal in the condenser, where much of the tar condenses out, passes down the annular space between the two cylinders and then through the seal and coolers. The calorific value of the combined gases is approximately 240 B.Th.U.

The successful working of the Maclaurin plant is due to the provision made for trapping the condensing tar and preventing it from running into the hotter regions below and thereby suffering decomposition, and eventually causing the coal to be bound together into an impenetrable mass.

Tar with some water collects in the trap where it acts as a seal, passes under the inner cylinder and overflows by the gas main. The gas must, therefore, pass through the cold fuel before it leaves the plant and in so doing is cooled down to about 70°. Little heat is lost, as both gas and coke leave the plant at comparatively low temperatures.

To avoid radiation losses the brickwork is made 18 in. thick, with a special non-conducting brick on the outside, the whole being enclosed in a metal casing. The tar yield is from 14 to 20 gallons, according to the coal used.

Some ammonia is given off in the direct distillation of the fuel, and a further portion is formed by the steam passing through the zone between 750° and 500°. This ammonia is carried forward with the gas, part condenses in the coolers and part is washed out in the scrubbers. The quantity obtained varies from 17 lbs. to 30 lbs. according to the quantity of nitrogen in the coal used. The ammonia liquor differs materially from ordinary gas-works liquor. It contains neither ferrocyanides nor thiocyanates, but a considerable proportion of poly-hydric phenols.

The cooled coke drops into a trolley running below the plant, which is elevated to the top of the coke bunkers of 110 tons capacity. The trolley is emptied on to coke screens, and in this way the coke is divided into three sizes, each size going to its respective bunker. These bunkers lie over the railway, so that wagons can be filled direct from them.

The quantity of ash contained in the coke naturally depends upon the ash contained in the original coal used, but the ash is not equally distributed throughout the different sizes of coke.

When washed trebles are used, the percentage of ash in the coke nuts agrees very closely with that calculated, but when large coal of a low caking index is used, a considerable concentration of the ash takes place in the dust, and frequently in the smaller size of coke. With such coal the large coke is found to be much freer from ash than the other portions.