# PRESIDENTIAL ADDRESS

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# Some Industrial Developments and the Chemical Engineer

The Report for last year submitted by the Council is one recording the continued and satisfactory progress of the Institution of Chemical Engineers, while the account of the many advances in chemical engineering so ably described by Prof. Hinchley in the January number of *The Industrial Chemist* is further evidence of the rapid development and growing importance of the profession.

I believe that chemical engineering can and should play a leading part in the development of new industries and in the progress of existing ones; and I wish in this, my second presidential address, to suggest that the chemical engineer should always be on the look-out for cases in which he can help, and to indicate one or two improvements by way of example which might thereby be effected.

The cultivation of the sugar beet is becoming an increasingly important feature of home agriculture and the manufacture of sugar from it, a new home industry.

The first beet sugar factory was opened at Cantley, in Norfolk, in 1912, the second at Kelham, in Nottinghamshire, in 1921; both had somewhat chequered careers. In 1924 a factory was started at Colwick, also in Nottinghamshire.

All three factories worked during the 1924–25 campaign, when authority for the payment of a subsidy was provided for under the British Sugar (Subsidy) Act of 1925.

The following figures will give some idea of the rapid growth of the industry:—

| Campaign. | Factories. | | Area under Sugar beet. | Sugar beet treated. | Production. | | Subsidy. | |
|---|---|---|---|---|---|---|---|---|
| | No. | Capital Total. £ | Acres. | Tons | Sugar. Tons | Molasses. Tons | Sugar. £ | Molasses. £ |
| 1924–25 | 3 | 1,887,489* | 22,600 | 183,713 | 23,915 | 5,701 | 465,798 | 26,241 |
| 1925–26 | 9 | 4,157,489 | 56,200 | 428,213 | 51,918 | 13,545 | 1,001,067 | 65,022 |
| 1926–27 | 14 | 5,882,489 | 130,000 | 1,129,205 | 146,000† | 39,700† | 2,847,000† | 353,000† |

* Includes Spalding, which first worked in 1926–27.
† Estimated.

It is expected that additional factories will be ready for the 1927–28 campaign at Bardney, King's Lynn and Selby, at an estimated capital cost of over £1,000,000, and capable of treating about a further 3,000 tons of beet a day; three existing factories are also doubling their resources.

The industry, therefore, is assuming considerable proportions, and employs a big capital that is now earning a good return; this, however, is in great measure due to the subsidy. For the years 1924–28 this subsidy is to be at the rate of 19s. 6d. a cwt. for sugar with a polarisation exceeding 98 degrees, for 1928–31=13s., and for 1931–34=6s. 6d.; these amounts are inclusive of the excise paid by the factories which, under the Finance Act, 1925, amounted to 7s. 5d. per cwt., allowing for the Imperial preference of 4s. 3½d. The corresponding subsidies for molasses are 8s. 10.9d., 5s. 11.3d. and 2s. 11.6d., respectively, if containing 50 to 70 per cent. or more of sweetening matter, with reduction for lower percentages. The commercial price of sugar is 33s. a cwt., the gross direct subsidy thus being 59 per cent., and the net subsidy 37 per cent. of the commercial price of sugar, but is subject to decrease after each triennial period.

The Act further provides for a minimum price of 44s. a ton for beet grown during the four years 1924 to 1927, the beet to be properly topped and washed, delivered into the factory sidings or flumes and to have a sugar content of 15·5 per cent., with an addition to or deduction from the minimum price at the rate of threepence in respect of each 0·1 per cent. above or below 15·5 per cent. as the case may be. In fact, however, the factories paid an average of 55s. 6d. per ton in 1925–26.

In a report on "The Results of an Inquiry into the Costs of Production, Yields and Returns in 1924," by the Agricultural Economics Research Institute, Oxford University, the net profit of 34 costed farms per ton of washed roots was 3s. 5½d.; the net gross price received being 50s. 9d. Under the head of "General Impressions" in the same report, the following passage appears: "Of the future it is not intended to prophesy beyond remarking that if a drop of 20s. a ton is indicated when the subsidy ceases, the farmer will have to rely for his profit on the indirect advantages the crop secures him, viz., the residual value of manures, cultivations, and the bye-products of the crop."

It seems doubtful, therefore, if the deductions drawn by the Oxford Research Institute are correct, and they are admittedly based on somewhat scanty data, whether—under existing conditions of the supply of raw material and of manufacture—the industry would be able to pay its way when the subsidy ceases.

What can be done then to enable the industry to survive on a commercial basis on the expiration of the subsidy?

There are two ways in which the actual cost of the finished article might be lessened, viz.:—

(1) By reducing the cost of the raw material, and

(2) by reducing the manufacturing costs.

As regards the first, the farmer can afford to take a lower price for his beets than he is now receiving, but he must learn to increase both yield per acre, and if possible sugar content as well. The yield per acre depends partly on efficiency of cultivation, partly on the strain of seed used, partly on the nature of the soil and partly on climatic conditions; to what extent the soil affects the sugar content is not so easily determined. Unfortunately, high yields and high sugar content do not necessarily go together. It is a matter for individual growers to determine, in accordance with local conditions, whether they should aim at producing quantity or quality of beet.

The yields per acre are improving; the average in 1924 was 8·2 tons, in 1925 it was 7·8 tons, and in 1926 it is estimated at 8·7 tons. These yields, however, are not so good as the continental ones, which for 1925 were as follows:—

| | | |
|---|---|---|
| Holland | .. .. | 13·42 tons |
| Germany | .. .. | 10·21 „ |
| Hungary | .. .. | 9·23 „ |

The average sugar content is also improving, as will be seen from the following figures:—

| | | |
|---|---|---|
| 1924–25 | .. .. | 16·65% |
| 1925–26 | .. .. | 16·36% |
| 1926–27 | .. .. | 17·00% (estimated) |

The Minister of Agriculture at a meeting of the Council of Agriculture for England on January 20, 1927, said that he was hopeful that the improvement in sugar yield per acre might enable the industry to adjust itself to the inevitable period of decreased prices, which must come as the rate of subsidy declined and finally ceased.

The attainment of increased yields per acre, and an increased sugar content, as well as cheaper cultivation and harvesting methods, are matters for the agriculturist rather than for the Chemical Engineer.

There is, however, an item of cost which the chemical engineer can help to reduce.

Certain average figures bearing on this point are given in a table of "Average Costs and Returns" in the Report previously referred to, for 34 costed farms growing sugar beet. They are as follows:—

| | |
|---|---|
| Yield of washed roots per acre .. .. | 10·2 tons |
| Cost of transport of washed roots per ton .. | 4s. 11½d. |
| Cost of transport as a percentage of total cost of production and delivery .. | 10·5 |
| Tare .. .. .. .. .. | 15·9% |
| Range .. .. .. .. .. | 8·7—45·5% |
| Approximate distance from Station to Factory .. .. .. .. .. | 28 miles |

In addition to 3 cwt. of dirt with the beets as delivered, there is the water content of the beets themselves amounting to about 75 per cent. of the total weight. It has been determined by experiment that the water content can be reduced to 7½ per cent. to obtain sound keeping qualities. Moreover, on receipt at the factory a certain amount of topping and removal of crowns has to be done, amounting to almost a further one-tenth of 1 per cent. of the weight of the beet.

The net result is that rather over three-quarters of the weight delivered to the beet sugar factories is useless material.

If water and useless material could be removed, before the beets are delivered at the factory, transport charges would be reduced and other advantages would be realised, all tending to reduce costs.

A process, invented by Dr. De Vecchis in connexion with the manufacture of beet sugar, was brought to the notice of the Ministry of Agriculture in 1924.

In this process the fresh beets are washed, sliced into cossettes and desiccated in a drying apparatus. The cossettes as they leave the drier are rigid and horny and in this condition they can be kept in suitable store rooms for several months without fermentation or loss of sugar. There are other features of the process that will be referred to later.

The Ministry of Agriculture arranged for experimental work on the process by the Institute of Agricultural Engineering at Oxford, and a progress report on the work by Dr. B. J. Owen, the Director of the Institute, was issued in August, 1926.

In this report the possibility of introducing a system of drying beet locally is referred to and it is stated that the Institute proposes to experiment further in devising suitable apparatus for cleaning, slicing and drying at the farm, and to give consideration to devising some inexpensive means of packing dried beet for various methods of transport.

These processes will require the generation of power at the farms, and this raises the question as to the possibility of using for this purpose the alcohol manufactured from the tops and crowns removed before the beet is sliced for drying. Since a large proportion of the beet sugar factories are situated in potato growing districts, small, damaged and surplus potatoes could also be used for alcohol production, and the beet-washing plant could no doubt deal with potatoes as well. Another raw material suitable for the same purpose would be beet slices, that is the beet residue after the extraction of the sugar; the residue, after fermentation, would still be available to meet stock feeding requirements. This is a matter that will be referred to later.

The design, layout and operation of plants for the preparation of the beets on the farms is well worth the attention of chemical engineers in view of the importance and increasing magnitude of the interests involved.

Let us now consider the possibilities of reducing manufacturing costs.

In a paper read before this Institution on April 14, 1926, Mr. Kwantes of the Cantley Factory described the various processes the beet is subjected to from the time it arrives at the factory until the sugar extracted from it is sent away. Some members of the Institution also had the privilege of visiting the Kelham factory and of being shown all through the plant.

In addition to the general operations of steam raising, power production, conveyance of materials from operation to operation, etc., there are the mechanical operations of washing and slicing, and the many subsequent processes involving some of the fundamental principles of chemical engineering. These are as follows :—(1) the extraction of the juice from the sliced beet by diffusion ; (2) the purification of the juice, known as epuration, by means of lime prepared in the factory ; (3) the precipitation of the excess lime with carbon dioxide gas obtained from the lime kiln, a process known as carbonatation, followed by (4) a filtration of the juice ; these two latter processes are repeated two and sometimes three times the juice being heated up after each filtration operation, and (5) treatment of the precipitate remaining in the filter or "scum-presses" for the removal of its sugar content and subsequent drying for use as a manure.

Before the purified juice is converted into crystals by evaporation of the water it is subjected to a sulphitation process with sulphur dioxide gas, followed by a filtration to remove any precipitate which may have been produced. The actual removal of the water is done in two stages, the evaporation proper in multiple effect evaporators, followed by the crystallising and centrifuging operations. The white sugar obtained is granulated and dried. The mother liquor or molasses also undergoes treatment to extract as much of its sugar content as possible ; and finally the exhausted slices have to be pressed or dried to remove water so as to make them suitable and transportable for cattle feeding purposes.

The De Vecchis process, to which reference has already been made, differs from the process just outlined. The extraction of the sugar from the dried cossettes is effected by lixiviation. The purification known as defecation is effected by lime followed by superphosphate, and the juice is then cleared by filtration. The subsequent operations follow normal practice.

In both these processes there are undoubtedly directions in which improvements and simplifications that would result in economies, could be made. This applies not only in connexion with the general layout, nature and installation of plant, and with general operating conditions, but also in connexion with the various operations special to the production of sugar from the beet. Questions concerning the effluent water and the disposal of waste and by-products are also becoming very important.

This industry, a comparatively young one in this country, was started to some extent on foreign capital, with a certain amount of foreign technical skill and, to a greater extent with foreign plant ; it is apparently still dependent on foreign or Dominion technicians for its development. In the recently issued prospectus of the Lincolnshire Beet Sugar Co., Ltd., the following paragraph appears :—

"Cultivation of beetroots, and the manufacture of sugar therefrom, are still in their infancy in this country, and it is necessary, therefore, in order to obtain the best results, to seek expert advice and management from countries where the industry is an old and well-established one."

It is evident that the industry should receive the closest attention of our best chemical engineers if it is to become firmly established, and be able to manufacture and market sugar in open competition conditions, when the subsidy comes to an end.

The introduction of the internal combustion engine some forty years ago has revolutionised many forms of transport. On January 1, 1926, according to the U.S. Bureau of Commerce Reports there were some 26 million motor vehicles in operation throughout the world with an average of 67 persons for each vehicle, the corresponding figures in Great Britain being, in round numbers 1,300,000 and 36 respectively, and in the United States of America 20 million and 6 respectively.

The extraordinary developments that have taken place in the use of the internal combustion engine have been rendered possible by the enormous and progressive increase in the world's production of petroleum estimated in 1926 to have amounted to 150 million metric tons, of which quantity some 70 per cent. was produced in the United States of America and only 1·7 per cent. in the British Empire. Of the 150 million tons approximately 30 per cent. may be taken as being gasoline or petrol.

Apart altogether from the question as to how long the world's supplies of petroleum will be equal to its requirements, the dependence of this country on imported liquid fuels, more especially for use in internal combustion engines, imported, moreover, in the main from foreign countries is a matter of some concern. Incidentally the cost of the petroleum products imported into Great Britain in 1926 amounted to £38,591,150, the value of the motor spirit being £21,567,931.

The question of alternative fuels received official consideration so far back as 1905, and was again the subject of enquiry by a Departmental Committee set up by the Government in 1918. On both occasions alcohol was the alternative fuel round which the enquiries centred.

The matter of the production of alcohol in this country, and in the Empire overseas, has been carefully investigated by the Department of Scientific and Industrial Research and, as a result, the conclusion has been arrived at that it cannot be made in this country from indigenous raw material in any appreciable quantity, or at a price that would enable it to be sold in competition with petrol at anything like the present price of the latter.

It has long been known that alcohol can be produced from the cellulose of the plant by converting it to fermentable sugars either by (a) chemical, or (b) bacterial processes. If therefore a cheap and simple process, either chemical or bacteriological, were available and could be applied commercially on a large scale, tropical and semi-tropical vegetation and waste vegetable materials generally might afford a practically inexhaustible reservoir of power alcohol.

This aspect of the question has been studied for the Department at the Bacteriological Laboratory of the Royal Naval Cordite Factory in Dorset. So far no results indicating the possibility of a practical process for the production of alcohol by means of a direct fermentation have been obtained, although considerable further light has been thrown on the problem.

The work on a process, chemical in its initial stages for making alcohol from the cellulose of the plant has been carried much further. It involves certain chemical engineering problems.

Vegetable materials such as those referred to above, consist essentially of cellulose, lignocellulose and hemicellulose and, for reasons it is unnecessary to go into now, it was decided to work on the hemicellulose content usually represented by pentosans. Before pentosans can be fermented, however, it is necessary to convert them into pentoses, which can be effected by an acid hydrolysis. The resulting pentoses are capable of ready fermentation by a certain type of bacterium which, on an average pentosan content of 20 per cent. of the raw material, yields 20 gallons of alcohol per ton of material of which about 10 per cent. is acetone, a very useful addition from the motor fuel point of view.

The conditions governing the hydrolysis of hemicelluloses, chiefly pentosans, were studied in the laboratory, several types of vegetable material such as tropical and semi-tropical grasses, rice and wheat straws, maize cobs, etc. being used for the purpose. It was established that anything like the drastic treatment necessary in the case of cellulose such as is employed in the Prodor process for the manufacture of glucose, leads to a complete destruction of the resulting monoses, and that mild hydrolysis is sufficient for the complete conversion of the pentosans into pentoses.

The laboratory experiments, which were subsequently confirmed in an intermediate scale unit of 160 gallon capacity, showed that, as a general rule, a pressure boil for 4 to 5 hours of a suspension of the material in water containing 0·6 per cent. of acid, calculated as sulphuric acid, and at a pressure of 10 lb. (112° C.) was sufficient for the conversion. When lower acid concentration was chosen, for instance 0·1 per cent., the pressure required had to be correspondingly increased. On the other hand, an increase in the percentage of acid allowed of a lowering of the pressure required.

A very considerable amount of work was involved before the fermentation of the pentoses extracted could be carried out satisfactorily in the intermediate scale unit, but it can now be said that, so far as the fermentation process is concerned, an inexpensive and readily controlled pure culture method has been worked out by which the hemicelluloses present in the materials referred to can be converted into a mixture of alcohol and acetone.

On the other hand the hydrolysis process on the lines described above, while presenting no difficulties in the laboratory, or even in the intermediate scale unit, where there were no restrictions on the materials used in the construction of the apparatus and plant, could not be performed on a manufacturing scale as autoclaves of acid resisting materials are not obtainable of sufficient size. Moreover, as the main object of the investigation was to devise a process for use in the Dominions and Colonies, simplification of both plant and process was of primary importance. It was decided therefore to ascertain whether less complicated methods could not be devised. For this purpose it was determined to investigate the effect on the pentosans of low temperature and of a minimum quantity of liquid of high hydrogen ion concentration. As a result of these investigations the following procedure was evolved for working a tank of 160 gallons capacity. The raw material is, if necessary, cut into a convenient size and then steeped for 4 to 6 hours at ordinary temperature in a 2 per cent. solution of sulphuric acid in the proportion of 1 to 10. After steeping the surplus acid is drawn off, leaving in the material from 1·5 to 3 times its own weight of diluted acid. This quantity could be considerably reduced by the introduction of suitable presses. The damp material is next steamed for 7 hours with live steam, the effect of this on the acid soaked material being sufficient to destroy all micro-organisms and their spores. The subsequent extraction of the pentoses is carried out under aseptic conditions and with sterile water collected from the excess steam used in the hydrolysis, thus securing a sterile mash without the need of a special pressure sterilisation process. Heating of the material under pressure, whether it is acid or neutral, is entirely eliminated and the process is simplified in important directions. Further, a solution of pentoses is obtained which in its fermenting qualities is found to be equal, if not superior, to the solution prepared by pressure boils.

Reference has been made to the possibility of using the waste materials of the beet sugar factory, supplemented possibly by small, damaged and surplus potatoes, for the manufacture of alcohol for use as a fuel on the sugar beet farms.

The application of the process just described to such materials has been investigated for the Department of Scientific and Industrial Research at the Bacteriological Laboratory of the Royal Naval Cordite Factory, and the results have indicated that these materials can be made to yield alcohol not only from the natural sugars, but also from the pentosan portion of their composition. The approximate yields obtained so far on a laboratory scale are as follows :—

Tops as collected 4½ gallons, dry 30 gallons per ton.

Crowns as collected 13 gallons, dry 53 gallons per ton.

Extracted slices, dry 35 gallons per ton.

As already mentioned, the process has so far been carried only to the intermediate scale unit stage, but the development of the plant on a scale suitable for employment on the farm should present no special difficulties to the chemical engineer.

I have dealt with an industry dependent on the earth for its raw material ; I now propose to consider very briefly an industry that derives its raw material from the sea.

What may be termed the by-products of the fishing industry include fish meal, glue, gelatine or isinglass, and oils.

On the East Coast of Britain the by-products industry is well established, but until recently little attention of a scientific nature has been paid to it. The fish available are cod, haddock, hake and similar white fish.

Fish meal is made from the heads, removed before curing, and offal generally, and the main treatment required is a drying one. Steam at a pressure of about 80 lb. is usually employed, but the resulting high temperature is detrimental to the quality of the meal when it is approaching dryness. Moreover, present methods require 1 ton of coal to dry 1 ton of material.

The annual production of fish meal is of the order of 40,000 tons from 150,000 to 160,000 tons of waste from the curing and splitting operations and from surplus fish. The industry is therefore a very considerable one, and would repay a scientific study of the processes involved with a view to improving the product, more especially by eliminating the fishy odour, and to reducing its cost.

The best fish glue is made from fish skins by methods evolved by Dr. Kernot for the Adhesives Research Committee of the Department of Scientific and Industrial Research, although they have not all of them been carried as yet to large scale commercial application.

The glue is odourless and possesses superior qualities as an emulsifying agent, and is equal, if not superior, in adhesive power to the best glue obtainable from land animals.

The plant is generally similar to that used when making animal glue, but as fish glue liquors are always very diluted, their concentration is an important problem in the manufacturing processes. The avoidance of high temperatures is very necessary here also. At present the only process suitable for the concentration of fish glue is the evaporation at reduced pressure. Film evaporation is detrimental, and a plant capable of evaporating large quantities of liquid in a short period without causing hydrolysis is badly needed.

Isinglass is made from the swim bladder of the sturgeon, and is used principally for clarifying wines, beers, etc., but the work referred to above has shown that it is possible, given suitable plant, to prepare it in odourless form from the swim bladders of other fish, and that even fish skins suitably treated can be used as substitutes for it.

Of considerably more importance is the fish oil industry. Apart from herring oil very little oil is prepared from the whole fish, but very large quantities are obtained from livers. Probably England is the big centre for the extraction of liver oils for technical purposes—although the quality is inferior to that of imported oils. I do not know of any plant in England which can be considered as really efficient because apart from the poor quality, very large quantities of oil are thrown away with the so-called "foots."

The usual practice in this country is to remove the cod livers on the trawlers and barrel them. On arrival at port these are sold to the East Coast oil factories, and have usually suffered some deterioration before the oil extraction process is taken in hand. To obtain high quality oil, especially for use in pharmacy, it is essential that it should be prepared from livers as fresh as possible. The German fishermen recognise this, and oil extraction plant is usually installed on their trawlers, with the result that their oil fetches £10 to £12 a ton more than the British fisherman gets for his. The matter of a design of a simple and efficient oil extraction plant, and of its installation on board trawlers, is worthy of investigation.

There is at present little in the way of a fish by-product industry on the West and South West coasts.

There the fish found are sea bream, mackerel, dog fish, sharks and other nature of oily fish. The oil is chiefly valuable for making calcium and aluminium soaps, which are mixed with mineral oils to produce railway axle grease and similar lubricants.

The by-products contain too much oil to allow of their being made directly into fish meal, and in any case, the oil has a higher value for use as a lubricant than the meal. It is therefore necessary, and well worth while, to remove the bulk of the oil from the material; experience has shown that this should be done before it is dried since drying tends to crack the oil and diminish its value.

There are one or two more or less experimental oil extraction plants but there is a great need for a satisfactory and economical plant to enable large quantities of by-products and glut fish to be dealt with, and thereby to establish what should be a profitable industry. As evidence of this, a typical case of which I was informed, may be cited. At a Welsh seaport 30 tons of sea bream were thrown overboard because there was no market for it. If suitable plant had been available there could have been obtained from this 7½ tons of meal of a value of £22 10s. a ton, and 3 tons of oil of a value of £48 a ton.

Great Britain's prosperity in the past has rested largely on her enormous deposits of high grade and cheap coal for her home industries, and which she has been able to ship overseas at cheap prices owing to low rail transport costs allowed of by the close proximity of mines to seaboard, and the reduction of freight charges made possible by the use of coal as ballast in outward sea journeys.

The quality of our coal is maintained and we have had recent experience of how favourably it compares with foreign coal, but its price has become very high.

The Royal Commission on the coal industry in its summary of findings and recommendations stated: "It is urgently necessary that new methods for winning and utilising coal should be sought for, and should be found, if the prosperity of the industry is to be restored and a proper standard of wages and working conditions assured to the workers."

The actual mining of coal is hardly a matter within the province of the chemical engineer. Coal as mined, however, is a long way from being suitable or satisfactory for many of the purposes for which it is required, and increasing attention is now being paid to its preparation for the market. This entails the provision and installation of suitable equipment for the cleaning, grading, etc., of the many varieties of coal, operations in the development of which on scientific lines the chemical engineer can assist.

Coal utilisation offers even greater scope for the chemical engineer.

The gas and coke-oven industries are chemical engineering industries par excellence, and the remarkable progress they have made in recent years is a standing example of the results of the application of science to industry. But the treatment of coal in other directions is becoming more and more one of the most important industrial questions of the day. There are many problems that should engage the attention of the chemical engineer such as the destructive distillation of coal at low temperatures and the treatment of the resulting cokes and tars, the preparation of coal and coke for use as pulverised and colloidal fuel, the liquefaction of coal and coal tars having for its object the production of fuel oil and motor spirit, and the conversion of water-gas produced from coke, mixed with additional hydrogen into liquid fuels suitable for use in internal combustion engines.

One of the outstanding directions in which there are possibilities of development in the coke-oven industry is in the economic use of coke-oven gas. It would hardly be an exaggeration to say that up to the present most of the gas from coke-oven plants has been wasted, for if used at all it has been used in direct competition with coal for such objects as power production, where it can command on a thermal basis a price little, if any, higher than coal itself. What must be realised is that coke-oven gas is a raw material capable of being profitably employed in a number of modern chemical manufactures.

Every day the importance of hydrogen, pure or even slightly impure, in chemical manufacture becomes more and more obvious. One of the biggest problems in front of the chemical engineer is that of making hydrogen at a low cost, and coke-oven gas supplies him with an important starting point for his investigations. Liquefaction of gas on a large scale for the purpose of separating its constituents is receiving the close attention of engineers, and requires even closer attention by chemical engineers than it has hitherto received except in a few efficient and specialised works. But liquefaction is not the only possible means of separating the constituents of coke-oven gas and thus of obtaining hydrogen from it. The possibility of such methods as centrifuging or of selective solubility under pressure can by no means be excluded. I mention these methods, not because I have any knowledge that they hold out possibilities of economic development, but because they are receiving the attention of competent chemical engineers abroad.

The use of hydrogen obtained from coke-oven gas has been considered hitherto mainly from the point of view of the manufacture of synthetic ammonia, and it would not be out of place to draw attention to the fact that nearly all plants designed for the manufacture of synthetic ammonia as a by-product from coke-oven gas are of foreign origin. The newer developments of the production of synthetic solvents and combustible liquids from mixtures of carbon-monoxide and hydrogen, and of the possibility of the hydrogenation of coal, already referred to, offer nearly virgin fields of development compared with the manufacture of synthetic ammonia, and give rise to possibilities for the use of coke-oven gas at present wasted. It is certain that these new processes can only be developed commercially if the hydrogen required can be produced at a considerably cheaper rate than that associated with present methods.

There is another field of development which has been opened up recently, and that almost accidentally. The Electricity Supply Bill, which has now passed into law, anticipates a large expansion in the production and consumption of electricity, and provides for an interconnecting system of transmission lines throughout the country whereby it will be possible to develop not only the areas of consumption, but also the areas of production. In considering the increased output of electricity, most people's minds are directed towards the erection and operation of large super-power stations. There is one unfortunate feature of a large super-power station which cannot be too often emphasised since it tends to commit the country to a permanent waste of coal. Even a large and well equipped power station for the sole production of electricity wastes about 80 per cent. of the heat of the coal. In actual practice it is necessary to select a site for a super-power station not necessarily in close proximity to the supply of coal, but rather with reference to the close proximity of large quantities of water to enable 80 per cent. of the heat of the coal to be wasted in the most economical manner. That is to say, that one of the main problems in front of the power electrical engineer is how to get rid of 80 per cent. of his coal in a way which is of no use to anybody, and at as small a cost as possible.

The importance of the Electricity (Supply) Act, 1926, to the chemical engineer rests in Section 23, which is as follows :—

> 23. (1) The Board and any local authority company or person producing electricity by means of the utilisation of water power, waste heat, or otherwise, may enter into arrangement for the purchase by the Board of any surplus electricity which the local authority company or person may be able to dispose of on such terms as may be agreed, and the Board may be authorised by order of the Electricity Commissioners to exercise such powers (including the power to break up roads, railways, and tramways) as may be necessary for the purpose of conveying the electricity so purchased.

By this Section it is open to the chemical engineer to regard electricity as one of the products of his manufactures which may be sold outside his works in addition to his other products. Practically for the first time in the history of this country electricity may become by this law an important by-product of chemical manufacture. This statement can be elaborated in the following way :—Chemical manufacturers, almost without exception, require steam and power in proportions varying between very wide limits. In soap works, for instance, or in an explosives factory, the demand for steam is very high, and the demand for power comparatively very small. In an electro-chemical process such as carbide manufacture, the demand for electrical power is so enormous compared to any demands for steam that its cost rules it out of practical politics in this country. But taking the chemical industries of this country as a whole, I think it would be safe to say that in a very large number of them steam is the primary, and power the secondary consideration. Hitherto works to which this applies have only been able to combine their steam and power production to an extent corresponding to their own power needs. When the combined production of steam and electricity is limited in this way, it may be possible to make power cheaper than it can be bought from external sources, but it is not possible to make it so cheaply as if this limitation is removed. The chemical engineer now has a broader problem to face, namely, to obtain as a by-product in the production of a given quantity of steam at specified pressure and temperatures, the maximum amount of electricity at the minimum cost. From the published figures that are available it appears that by the use of high pressure turbines or high pressure reciprocating engines, it is possible to convert at least 5 per cent. of the heat of the coal into electricity and recover at least 70 per cent. in the form of steam of a pressure and temperature necessary for process purposes, that is to say, by the use of such plant a very large proportion of the total heat of coal can be usefully consumed instead of only about 20 per cent. as in the case of an efficient power station. There are no figures available enabling anything like an accurate estimate to be given of the amount of steam which is used for process work in large units ; the only statistical figure we have to go on is that the consumption of coal in the country for general manufacturing purposes is approximately sixty-five million tons. In order to show the importance of the simultaneous production of process steam and electricity, both to the chemical industry and to the country, I am going to make what I am sure you will all agree is a guess, that at least ten million tons of coal a year are at present used in raising steam for process and general heating work without the production of power. On the conservative figure that if the production of power and process and heating steam were combined, 5 per cent. of the heat could be so converted into power, it follows that an amount of electricity corresponding in heat value to half a million tons of coal could be obtained. The present quantity of electricity generated in generating stations requires a consumption of eight million tons of coal and is carried out with an average efficiency of 12 per cent., that is to say roughly in generating stations at present the heat of one million tons of coal is actually turned into electricity. Thus by the manufacture of electricity as a by-product, from every ten million tons of coal used in the production of steam for purely process and heating purposes, it should be possible to increase the amount of electricity generated per head of the population by 50 per cent.

The magnitude of these figures shows the great importance of the subject, not only to chemical engineers, but also to those who are looking forward to the development of big stations solely for the supply of electricity. It must be recognised that the feasibility of introducing any such methods would be dependent also on economic considerations such as capital cost of plant, etc.

I would conclude by repeating that the possession of very large quantities of coal was the main source of Great Britain's commercial supremacy in the past. The development elsewhere of water power and of liquid fuels has somewhat affected this supremacy.

There are, however, still vast resources of coal in the country. What is necessary at the present time is intensive work in connexion with the enormous potentialities opened up by modern developments in the various methods of treating and using this coal, and it is here that the chemical engineer should take a leading part.

On the motion of Sir Alexander Gibb, seconded by Mr. F. H. Rogers, the President was heartily thanked for his Address.

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