Future Methods Of Utilizing Coal*

Economic Problems That Are Beginning to Attract Attention

By Prof. C. F. Hirshfield

THERE is at the present day a certain amount of coal buried in the earth's crust. Coal is being slowly formed at some points on the surface of the earth, but the rate of formation is so slow in comparison with the rate of consumption that for all practical purposes the supply available for human consumption may be assumed to be that already formed. If this view is taken, it is evident that the amount of coal which can be used by man in the future is definitely limited; when he has used up the coal now in the earth's crust, or that part of it which he can extract, there will be no more available for use.

The estimates of the length of time which will elapse before this condition is attained vary greatly, but most of them allow humanity at least a few hundred years before the exhaustion of all available coal. Opinions as to what may happen when the time of ultimate exhaustion arrives are equally variable. Some believe that humanity must perish because of the enforced cessation of industries and because of the impossibility of keeping warm during the cold seasons of the year. Others believe that by that time hydro-electric development will have been carried to such a point that electrical energy will entirely take the place of heat derived from coal. Still others are satisfied to let the future take care of itself and to assume that the human brain is going to be able to continue to devise methods of changing the environment to suit the needs of the human animal.

I am inclined to take the last view myself, as I believe that the centuries of human history which are available show that each successive generation has become better able to force its dictates upon nature rather than to be subservient to the unrestricted action of natural forces. In other words, subsequent generations will be better able to care for themselves than the present generation and there is no need to waste good time and effort in trying to solve their problems for them with a smaller stock of knowledge and a narrower vision.

In taking this viewpoint it is not necessary to hold ourselves responsible to future generations for the use we make of the coal stores which we are depleting at such a rapid rate. We may consider ourselves free to use this material as our industrial development requires, though we are, in a certain sense, morally bound to make that usage as economical as possible on the basis of the general principle that it is not good economics to waste wealth of any sort.

If, then, we attempt to look into the future for the purpose of predicting the methods which will be in use for the utilization of coal, we must not warp our vision by an erroneous assumption of the necessity of conserving the supply. We must rather study industrial developments of the past and after discovering their general trend, attempt to apply this knowledge to the particular field under discussion.

It has been characteristic of nearly all industries that they started in a small way under conditions which did not require the most economical production. Thus the shoe industry was started by numerous individuals scattered over the country, who purchased leather, nails, thread and other raw materials in small quantities and then worked them up into shoes on individual orders received from people living in the immediate neighborhood. The modern packing industry sprang from the small butcher who slaughtered for local consumption and disposed of the hides and other byproducts in the easiest way possible. The clothing industry was originally confined to the home, the land or the live stock producing the raw material, which was worked up by the family of the owner into the clothing required by that family.

All of these industries have grown until they are scarcely recognizable as the offspring of their forebears. This has been brought about by organization, which is merely the combination of capital and the division of labor for the purpose of producing the biggest possible yield from given raw materials or natural supplies.

In the shoe industry scientific development produced the marvelous machines which are now used in producing leather and shoes and the railroads which later transport the factory-made product to the scattered consumers.

In the packing industry the refrigerator car made

possible the concentration of the slaughtering industries and, coupled with mechanical and chemical invention, assisted in building up large modern plants.

Spinning and weaving machines, cutting, sewing and pressing machines, coupled with the railroads, have made possible the huge centralized clothing industries of the present day.

The study of the packing business tends to throw considerable light upon the probable future development of the coal industry. It is not so many years ago that, in this country at least, meat on the hoof was so plentiful that it could be slaughtered in most expensive ways and still be sold at a profit at such a low figure as to bring it within the reach of practically all families. Conditions are now different and meat on the hoof is comparatively scarce. It therefore brings comparatively high prices and if all or practically all of the purchase price, transportation and slaughtering expenses had to be borne by the meat and hide, the prices of these commodities would be so high as to put them beyond the reach of many families even in this comparatively opulent country.

But the modern packing house manages to sell every part of the animal for some purpose. Some parts, such as those sold in the form of dressed meat, are disposed of after little modification, while others, such as horns, hoofs and fat, pass through elaborate manufacturing processes before they are ready for the market. When it is remembered that every one of the numerous products is sold on the average at such a price as to bear its share of the cost of the animal, of its transportation, and its slaughter and dressing, it is evident that the principal product, meat, can be sold at a lower price than would otherwise be possible. Moreover, waste has been reduced to a minimum; all parts of the animal which cannot be used for food are used for other purposes.

The coal industry, particularly in this country, is in much the same position to-day as would be a packing house which produced meat only. Coal is removed from the mine, put in marketable condition with the minimum possible expenditure and shipped to the consumer. The greater part of it is burned under boilers just as it is received or after breaking to smaller sizes.

As the supply in sight in the ground decreases, as mines become deeper and as freight rates increase, coal becomes more and more expensive. This process must continue so long as the methods at present in vogue in the industry continue and the cost of coal must ultimately become a serious burden on industries in which the coal charge forms a large fraction of the total charge. In view of what has happened in other industries it is but natural to assume that when economic pressure makes it necessary, the coal industry or the methods of utilizing coal will be so modified as to obtain the maximum possible number of products with the maximum possible economic value from each ton mined, provided such products are obtainable.

We are accustomed to think of coal as merely so many stored or latent units of heat energy purchasable at so much per thousand or million. It is far better, however, to view it as a collection of chemical substances and combinations which are capable of almost an infinite number of transformations and recombinations to form innumerable new end products. If coal were merely a collection of units of heat energy the cost per unit would of necessity continue to increase until it reached a prohibitively high value. Taking the view just suggested, however, it is possible that chemical jugglery of the constituents may be made to develop substances marketable at such prices as to materially reduce the necessary selling price of units of heat energy.

The principal constituents of coal are carbon, hydrogen, oxygen, nitrogen and sulphur, and these are the blocks out of which innumerable organic and inorganic chemical compounds are built. Just how these various constituents will be liberated or recombined for the purpose of increasing the economic value of a ton of coal in order that the selling price of units of heat energy may be kept down to a reasonable figure, must be more or less a matter of speculation. It is, however, pertinent to note that processes of this kind are already in use in some of the European countries and particularly in Germany, and it is reasonable to suppose that future development will follow along some such lines as those already partially developed. An investigation of these methods may therefore assist in

arriving at a more correct prediction of future methods.

In general, development is carried on along three lines: First, the thermal efficiency of heat engines and plants is brought to the highest possible figure in order to reduce to a minimum the number of heat units which must be purchased by anyone concerned in the generation of power; second, byproduct fuels of various varieties are made from the raw coal, or from the coal in the process of utilization and some of these may have such desirable properties as to be worth more per unit of heat energy than is the raw product. Their use or sale therefore tends to reduce the price paid for heat units in the raw coal. Third, many byproducts useful in numerous arts are made and their economic value helps to reduce the cost at which units of heat energy or their products must be sold to yield a profit.

It will be observed that when the coal-mining and consuming industries develop in this way, they begin to approach the condition of the modern packing industry. The capital involved is enormously increased; many more kinds of labor are required and the subdivision of labor is carried to a far greater extent; and the economic value of the product per ton of raw coal is enormously increased.

The parallel may be drawn still more closely. Meat for human consumption may be considered the primary product of the packing industry. The selling price is continually increasing, but the rate of advance is kept lower than it otherwise would be by increasing the number of products per unit of raw material, giving a greater economic value to the products per unit and reducing the charges against the primary product. Heat energy may be said to be the primary product of the coal industry and the selling price of this is continually increasing. The rate of advance is kept lower than it otherwise would be by increasing the number of products per unit of raw material, giving a greater economic value to the products per unit and reducing the charges against the primary product.

Development along these lines has thus far progressed along two principal paths. The raw coal is subjected either to a destructive distillation process with the exclusion of air, or to a process of incomplete combustion in the presence of air. The former method yields a solid fuel called coke; combustible gases of a more or less permanent nature; condensable vapors of great chemical and fuel value; and other substances, such as ammonia, cyanides, sulphur compounds and others. The latter method yields solid, incombustible refuse or ash of comparatively small value; large quantities of combustible gas of great value; considerable vapors which are becoming of greater chemical importance daily and are also becoming available as fuel; and small quantities of chemical compounds of more or less value.

By such means as these fuel material becomes available in solid, liquid and gaseous forms, and the particular variety best suited to any use may be chosen therefore if price permits. It is, of course, impossible to obtain more heat units than were originally contained in the fuel. There is in reality always a loss in these processes, but the thermal efficiency with which the smaller number of resulting heat units can be used may more than balance the thermal losses occurring during the modification of the fuel. Great developments have been made in the use of gaseous and liquid fuels during the past few years. It is now possible to use such fuels for the generation of steam, for industrial heating, and for the operation of prime movers at efficiencies much higher than seemed possible of attainment a short time ago. Surface combustion and the internal-combustion engine in its various forms are pointing out lines of development leading toward constantly increasing thermal efficiencies.

These statements must not be interpreted as an argument for the immediate adoption of gas firing and of the universal use of the internal-combustion engine. Other matters must be given consideration as well as the cost of fuel. The cost of capital is of equal importance.

At present the costs of capital and of fuel are both increasing, but the cost of the latter is increasing more rapidly than that of money. Even now the cost is such as to warrant greater capital investment for procuring greater thermal efficiency than could have been justified a few decades ago. Ultimately the cost of fuel must rise to such values as to warrant the investment of

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the necessary capital and the training of the necessary labor to make possible the use of fuel in such ways as to produce the greatest economic production per ton of raw material.

When that time comes it is probable that coke, or something resembling it, will be the principal solid fuel; gases formed during the production of the solid will be used in internal-combustion engines, or by surface combustion, or in ways not yet discovered; and liquid fuels formed during the production of solid fuel will be used in high-efficiency, liquid-fuel engines. Before they are used the liquid and gaseous fuels will be robbed of many valuable constituents, which will be used in producing fertilizers, medicines, paints, dyes, preservatives, waxes, flavoring extracts, commercial chemicals and many other products yet undreamed of.

Summarizing these ideas, it seems probable that:

1. Improved or more economical methods of utilizing coal will not and need not be brought about by any consideration of conservation as now ordinarily understood.

2. Such methods will be brought about by cumulative economic pressure due to the natural operation of increased demand for fuel combined with decreased quantities and increased cost of mining and transportation.

3. When such methods are thus forced upon humanity they will follow, in a general way, the course developed in other industries under the force of similar circumstances.

4. These methods will consist of a preliminary treatment of the raw material to produce fuels with different physical and chemical characteristics which will adapt each form to use in particular kinds of apparatus or in particular industries.

5. Coincident with this treatment will be produced numerous non-fuel byproducts of great value in the then existing markets.

6. The spreading of the cost of the raw material over so many products will prevent the excessively rapid rise in the selling price of fuel per heat unit and this, combined with high efficiency methods of utilization made possible by the relative prices of fuel and

capital, will yield the same sort of an economic balance as now exists. Humanity will probably then, as now, bemoan the fact that it could not have lived several generations before, when fuel was "cheap," and will probably express great sympathy for the coming generations that will have to face the problems of life with a still more depleted coal supply.

Many will probably object that the cost of modifying coal, as, for instance, by the destructive distillation process, has always been so expensive that little is to be hoped for along such lines in the future. In answer to such criticisms, it is only necessary to point out the fact that despite the rising prices of coal, labor and capital, the selling price of gas made by such processes has steadily decreased. It is admitted that further decrease cannot be brought about by exactly the same methods as have been used in the past, but it shows very little faith in the progress of the human race to assume that the present status in any industry represents the ultimate development of which humanity is to prove capable.

Formulas For Glass Manufacture*

THE Institute of Chemistry has given out an account of the work of the Glass Research Committee appointed by the council of the institute to conduct investigations with the view of arriving at suitable formulas for laboratory glassware, miners' lamp-glasses, combustion tubing, resistant glass for pharmaceutical products, glass for X-ray bulbs, etc. The main part of the report is here reprinted, and is of particular interest at the present time.

Since October, 1914, the research has been continued uninterruptedly, the chief aims being:—(i) to produce working formulas for all glasses used in laboratory work, and (ii) to ascertain the influence of various ingredients on the physical and chemical properties of glasses. The work was extended to include glass for miners' lamp-glasses, at the suggestion of the Home Office; and also glass for ampoules, to meet the needs of the wholesale pharmaceutical chemists engaged in the production of army medical requirements. The committee also examined and reported on samples of British and French laboratory glassware, produced since the beginning of the war, a number of specimens being made from formulas similar to, and in some cases almost identical with, those recommended by the committee.

The committee has had before it many specimens of glasses used for various purposes, of which analyses have been made by Mr. Bertram Blount, Mr. W. C. Hancock, and Mr. Otto Hehner. It has been found, however, that mixtures prepared in accordance with the analytical results were not always satisfactory; but the analyses were helpful in suggesting synthetic experiments, and during recent investigations some intricate analyses made by Mr. G. J. Alderton under the supervision of Mr. Blount have proved especially valuable. Apart from the analyses, the work has been almost entirely carried on at King's College by Prof. Herbert Jackson and Mr. T. R. Merton, and by the former at his own house. The work has involved a careful study of the chemistry of silicates, aluminates, borates, etc., in their relation to the manufacture of glasses.

Up to the present time, the research committee has reported eleven formulas for glasses for various purposes based on the results of about 400 experimental melts on a scale large enough for drawing rods and blowing small vessels. In addition, a very great number of experiments have been made in order to study the influence of the various constituents employed. No formula has been issued without submitting the specimens made to rigorous tests to prove their suitability for the purposes for which they are intended. Moreover, by varying the experimental working conditions, it can be said with reasonable confidence that the mixtures will prove equally satisfactory under the actual working conditions of a glass furnace. The question of workable temperatures has been carefully considered, and so far as it is possible to judge, the melts on a small scale indicate that even better results will be obtained on the industrial scale. This view has been justified by the samples already received from manufacturers who have tried some of the formulas.

In deciding the formulas it has been found necessary to direct special attention to the proportions of basic and acidic substances in respect of the action of glass mixtures on clay crucibles during fusion, and it has been shown by careful investigation that the formulas proposed give melts in which the influence of the ingredients of the crucibles is very slight and in some cases practically inappreciable.

The following formulas have been communicated to a number of manufacturers who have expressed their interest in the progress of the investigation and to scientific workers who are conducting experiments.

*From Nature.

Soft glasses, suitable for ordinary chemical laboratory ware.

Parts		Parts	
(1) Sand.....	67.0	Calcium carbonate	11.6
Sodium carbonate		Alumina (Al ₂ O ₃)	6.5
(Na ₂ CO ₃).....	34.2		

A soft glass which does not give up alkali readily to water, works well in the blowpipe, and does not devitrify readily.

Parts		Parts	
(2) Sand.....	67.0	Calcium fluoride..	1.6
Sodium carbonate		Alumina (Al ₂ O ₃)..	8.3
(Na ₂ CO ₃).....	29.0	Boric anhydride	
Calcium carbonate	9.6	(B ₂ O ₃).....	2.0

A soft glass of higher quality. Does not give up alkali under severe tests. A kindly working glass before the blowpipe, and very difficult to devitrify.

A resistant glass suitable for pharmaceutical purposes, ampoules, etc.

Parts		Parts	
(3) Sand.....	67.0	Potassium nitrate	1.0
Alumina (Al ₂ O ₃)..	10.0	Sodium carbonate	
Calcium carbonate	12.5	(Na ₂ CO ₃).....	17.0
Magnesia.....	0.5	Boric anhydride	
		(B ₂ O ₃).....	8.0

This glass is intermediate in hardness between soft glass and combustion tubing, is highly resistant to chemical action, withstands changes of temperature well, and should be a very suitable glass for high-class beakers, flasks, etc.

Glasses for combustion tubing.

Parts		Parts	
(4) Sand.....	68.2	Sodium carbonate	
Alumina (Al ₂ O ₃)..	6.2	(Na ₂ CO ₃).....	5.5
Barium carbonate	8.8	Boric anhydride	
Calcium carbonate	13.0	(B ₂ O ₃).....	5.5
Potassium nitrate.	4.3	Calcium fluoride...	1.0

This glass resembles Jena combustion tubing very closely indeed. It has practically the same fusing point. It fuses on to Jena glass perfectly, and is indistinguishable from it before the blowpipe and in its behavior on prolonged heating below its fusing point. The presence of the small quantity of calcium fluoride facilitates the incorporation of the ingredients. The sodium carbonate can be reduced to 1.34 parts provided 7.93 parts of anhydrous borax be used in the place of boric anhydride.

Parts		Parts	
(5) Sand.....	68.2	Sodium carbonate	
Alumina (Al ₂ O ₃)..	6.2	(Na ₂ CO ₃).....	5.5
Barium carbonate	8.8	Boric anhydride	
Calcium carbonate	14.2	(B ₂ O ₃).....	5.5
Potassium nitrate.	4.3		

This glass is practically of the same composition as (4). It is not so easy to make or to work, but it does not become so opaque as Jena combustion tubing on prolonged heating. As in No. (4), the proportions given for sodium carbonate and anhydrous borax can be substituted for the figures for sodium carbonate and boric anhydride.

Miners' lamp glasses.

Parts		Parts	
(6) Sand.....	65.0	(Sb ₂ O ₃).....	1.0
Alumina (Al ₂ O ₃)..	1.0	Potassium nitrate	3.0
Calcium carbonate	0.6	Sodium carbonate	
Arsenious oxide		(Na ₂ CO ₃).....	14.0
(As ₂ O ₃).....	2.0	Boric anhydride	
Antimony oxide		(B ₂ O ₃).....	24.0

A colorless and fusible glass withstanding rapid changes of temperature exceptionally well.

Parts		Parts	
(7) Sand.....	65.0	(Sb ₂ O ₃).....	1.0
Alumina (Al ₂ O ₃)..	1.0	Potassium nitrate	3.0
Calcium carbonate	0.6	Anhydrous borax	
Arsenious oxide		(Na ₂ B ₄ O ₇).....	26.68
(As ₂ O ₃).....	2.0	Boric anhydride	
Antimony oxide		(B ₂ O ₃).....	5.5

The same glass as (6), but the ingredients have been varied to avoid the use of so much boric anhydride, which is at present apparently difficult to obtain on a commercial scale.

Resistance-glass.

Parts		Parts	
(8) Sand.....	65.5	Sodium carbonate	
Alumina (Al ₂ O ₃)	2.5	(Na ₂ CO ₃).....	10.2
Magnesia (MgO)	5.0	Borax anhydrous	
Zinc oxide (ZnO)	8.0	(Na ₂ B ₄ O ₇).....	13.0

A glass almost identical in its general behavior with Jena resistance glass; withstands changes of temperature well, but, like Jena, is not suitable for working before the blowpipe. It darkens and tends to devitrify; operations—such, for instance, as sealing side tubes into flasks—are difficult, if permanent and neat joints are required.

Formula No. 3, recommended for pharmaceutical purposes, ampoules, etc., may be substituted for the resistance glass with advantage, as the ampoule glass lends itself very well to blowpipe work, and is also especially resistant chemically.

Alternative for combustion tubing.

Parts		Parts	
(9) Sand.....	72.0	Potassium nitrate	
Alumina (Al ₂ O ₃)..	10.0	(KNO ₃).....	3.0
Calcium carbonate	11.0	Sodium carbonate	
Magnesia (MgO)	0.5	(Na ₂ CO ₃).....	11.2
		Borax anhydrous	
		(Na ₂ B ₄ O ₇).....	7.2

This glass is capable of withstanding high temperatures and rapid changes of temperature; works well before the blowpipe, and is free from the chief defect of Jena glass—namely, the readiness with which it becomes cloudy, and finally quite opaque after prolonged use.

By slight modifications of this formula, almost any degree of hardness can be obtained.

In formulas (8) and (9) substances such as magnesia (MgO) and zinc oxide (ZnO) can be added in the form of carbonates if the actual percentages of MgO and ZnO respectively present in the carbonates are known.

Soft soda-glasses suitable for tubing and X-ray bulbs.

Parts		Parts	
(10) Sand.....	68.0	Potassium nitrate	
Alumina (Al ₂ O ₃)	4.0	(KNO ₃).....	14.5
Calcium carbonate		Sodium carbonate	
(CaCO ₃)..	12.8	(Na ₂ CO ₃).....	26.0

Parts		Parts	
(11) Sand.....	68.0	Potassium carbonate	
Alumina (Al ₂ O ₃)	4.0	(K ₂ CO ₃)..	10.0
Calcium carbonate		Sodium carbonate	
(CaCO ₃)..	12.8	(Na ₂ CO ₃)..	26.0

These glasses do not lose their easy-working qualities after repeated heating and blowing, and are plastic over a long range of temperature. They require a temperature of at least 1400 to 1500 deg. Cent. for complete incorporation of the ingredients in order to obtain that homogeneity which is necessary for resistance to rapid changes of temperature and ease of working before the blowpipe.

No. (10), containing potassium nitrate, is considered the better of the two, and is more easily incorporated.

The committee considers that the formula obtained and the work done on the various glasses justify it in the opinion that there is now information available for the manufacture of all the important glasses used in the laboratory and for industrial purposes, which have hitherto been mainly obtained from abroad.