The second type of receptor is one which is concerned with the not blue aspect of vision of the hypochromat. These may be cones, of which there need be only one variety for the hypochromat.

The third type of receptor would be functional in normal vision, and it seems as if this second variety of cone were one that distinguishes red from not red, and according to the activity of this variety the stages between normal vision and complete red-green confusion can be bridged.

Therefore, normal vision may be due to a receptor which gives rise to a red sensation, one which gives rise to a blue sensation and one which gives rise to a not blue, not red sensation which, of course, corresponds to green sensation. The actual wave-lengths of radiation that stimulate the several receptors are not known. The real difference between various hypotheses is the extent and region of the spectrum which stimulates the end-organs.

In the Young-Helmholtz hypothesis the type of receptor responsible for the sensation of red is stimulated by almost the whole of the spectrum, but most strongly by the long wave-length end. The receptors for green are stimulated by almost the whole spectrum, but most strongly by the mid-region; and those for blue are stimulated by a large extent of the spectrum, but most strongly by the short wave-length end.

'Red' light of longer wave-length than 6200 A. is supposed to stimulate the red receptor only, whilst shorter wave-lengths will stimulate the red receptor to decreasing degrees, but the other receptors to increasing extent, hence the change of colour with wave-length.

## Sources of Cheap Electric Power*

By PROF. FRANCIS G. BAILY

THE general idea of the scheme of production of electric energy proposed takes as its basis the complete linking up of all parts of Great Britain by the Grid, and the subsidiary lines fed from it or from the stations directly. All stations are connected to the Grid, and as well as supplying their local consumers, put the additional power into the Grid as required. This is the well-known main function of the Grid. It is here submitted that this leads to a different scheme of generation from that now followed, and that sources of cheap power are rendered available that previously could not be utilised economically.

The questions to be considered are: (1) The proportion of consumers who are within economic distance of a pit-head station. (2) The quantity of very cheap coal that is available. (3) The relative advantages of widely spaced large stations and more numerous small stations. (4) The opportunity offered by the Grid to bring into economical use pit-head stations at small isolated mines, power from factories using industrial steam, power from coke-oven and blast-furnace gas and hydro-electric stations. (5) The cost of transmission of electric power as compared with the carriage of the equivalent coal by rail or ship. (6) The effect of a substantial reduction in the cost of generation on the cost of distribution, and the selling price of electric energy.

The first question to be considered is whether pit-head production will so much limit the position of the sources of supply as to involve a great distance of transmission to a large part of the population.

If a distance of forty miles be regarded as still in the neighbourhood of the coalfields, a map of the coalfields shows that most of Great Britain is within this distance. A line across Scotland from Montrose to Arrochar on Loch Long is the northern boundary, and a line from Hull to Bournemouth, and up to Taunton in Somerset, marks the southern and eastern limits. A small part of Wales is also outside. Two-thirds of the population live in the area, and if London be omitted as a special case, only one-fifth of the rest are outside. There is also a probable coalfield in Lincolnshire, which if it materialises will bring in a good part of this fifth.

To a large extent, the population has gathered round the coal pits, and there are practically no large towns, except seaports, that do not lie within easy reach. A scheme depending on nearness to coal pits will have a large field for its operations, and it will in no way act prejudicially on parts which it may not be able to benefit.

It is proposed to use the lowest grade and waste coal, and the proportion required may be up to 10 per cent of the total coal raised. If the outputs of the different areas be examined, it is found that this proportion will in all cases be adequate for the population of the area. In some areas—Durham, South Wales and part of Yorkshire—where there is much less waste coal, the quantity of coal raised is so large that not more than 2 per cent will be required, which is easily provided from waste.

### WASTE COAL

The term 'waste coal' will here be used to include all coal in the seam that is not at present sold, but

* From the presidential address before Section G (Engineering) of the British Association, delivered at Aberdeen on September 6.

is, or can be, brought to the surface ; and coal of poor quality that will be profitably used in the pit-head station, instead of being extensively cleaned for sale.

Of the dirty coal that is at present raised and remains as the residue of cleaning operations, some is dumped on to waste land and some into the sea, but the greater part is burnt in the furnaces of the mine power-station. The consumption is wasteful in the extreme, for burning is the cheapest way of getting rid of the otherwise useless material. About 6 per cent of the coal raised is used to produce steam for power to work the mines, whereas in a colliery where the coal is scrupulously saved and there is little waste, it is found that the fuel required is only 1·25 per cent of the coal raised, and the quality of it is exceedingly low. Hence some 5 per cent is immediately available for other purposes if it is used economically, to which can be added what is actually thrown away. The use of coal cutters and dry-cleaning processes, which are cheap to operate but increase the proportion of waste, will be more used if this is saleable.

Summing up all these actual and prospective sources of low-grade coal, it may be estimated that if an overall price of 5*s*. per ton at the cleaning floors were offered, in most districts a quantity equal to 10 per cent of the coal raised would be readily obtained, with a smaller proportion in the rest, and that this would yield some 18,000,000 tons per annum, with a calorific value averaging 10,000 B.TH.U. per lb. This is 50 per cent more than is used to produce the present output of all the generating stations.

The general scheme should permit of using the waste coal from as many pits as possible, including even small isolated mines, for they assist in supplying the Grid at points otherwise unprovided for, and reduce the distance of transmission. What the lower limit of economical pit station will be need not be elaborately discussed, for the isolated pits provide only a small part of the total coal, and their exclusion does not materially affect the available supply.

The scheme will evidently provide an important amount of cheap fuel, and will permit of power stations of a size that ensures a low figure for cost of plant and running costs, so that the low price of the fuel is not offset by any increase in cost in other directions. It is true that the stations will not be placed in the towns, and to that extent distribution costs are increased ; but, on the other hand, land is cheaper, and it is being found that a station consuming many hundred tons of coal a day will compel the use of expensive remedies against sulphur and dust, so the advantages of an urban site will be sensibly diminished. Moreover, most of the large towns are not far from coal mines, and the cost of transmission will be very small.

An argument that has frequently been brought against the pit-head station is that there is little likelihood of a sufficiency of cooling water for the condensation of exhaust steam, in order to produce the high vacuum that the turbine can make use of. But the gain in efficiency due to the high vacuum is often exaggerated by failure to apply comparable conditions and to take recent improvements into account. It may be claimed that the absence of cooling water can be definitely disregarded as a disability in the use of pit-head stations.

### INDUSTRIAL STEAM

Another source of cheap power may be found in the proper utilisation of industrial steam. Many industries need low-pressure steam in their processes, and use boilers working at a pressure of 50 lb. or less. There is no difficulty in producing steam at 350 lb., superheating it and passing it through steam turbines, to exhaust at the required low pressure, and the steam so delivered is in all respects as good as that produced directly from boilers, as it does not come into contact with lubricating oil. The thermal efficiency of the turbine is 100 per cent, less the small radiation losses and bearing friction, for the rejected heat of the exhaust steam is used for the other purposes, and all steam friction loss is retained as heat in the steam. If the factory electric station is connected to the Grid, even a small one may put in all its spare output, no matter how irregular that may be, provided that consumers are not too far away, and that it can supply the energy at a price which will benefit all parties.

How much power can be obtained from this source it would be laborious to ascertain. Each factory would require separate consideration, and the cost of altering existing boiler plants would be important. But the change can be introduced gradually, new factories or renewal of plant affording opportunities, until all suitable factories are absorbed into the scheme. By that time the increased demand will easily take up all the power without disturbing the other sources.

The items in the cost of a unit have of recent years been codified and separated into parts dependent on the load factor and those that are independent, together with the influence of the size of the station. The costs for a normal station of 100,000 kw. and for a pit-head station of the same size have been calculated, assuming certain conditions.

At all load factors, the reduction in cost at the pit-head station is about one twentieth of a penny per unit. While this reduction does not look impressive when compared to the usual charges for lighting, it makes a substantial difference to the cost of the unit for domestic heating, which

is now down to 0·5*d*. in some places; and it will be shown that any lowering of cost of production is followed by a decrease in cost of distribution, so that there will be a beneficial improvement on the first economy.

### Cost of Transmission

The position of generating stations brings in the cost of transmission. In the coal areas, the numerous sources of supply will on the whole reduce transmission costs, but the supply of power to outside areas depends chiefly on the cost of electric transmission, as compared with other methods.

The cost of long-distance transmission of electric energy has been much reduced by increased voltage, and by reduced cost of transformers and transforming substations. It is considerably influenced by load factor, for capital charges and wages are constant, while line losses are much reduced on low load factors. For any distance of importance, the Grid at 132,000 volts will be the usual means, and the cost of transmission, when worked out for a distance of 100 miles, is only one third of the cost of carriage by rail of the corresponding quantity of coal. For shorter distances, the proportion varies somewhat, but it is always small. Carriage by sea, if the distance is considerable and both coal pits and generating stations are near the coast, is much cheaper, and coast towns distant from the coal areas will not be affected.

In the foregoing calculations of costs, the item of local rates has been omitted, for rates vary in different districts, and a general figure is not possible. The present charge for rates on electric supply stations is very high, and they have not come under the recent reduction of rates on machinery. Roughly, the item of rates on the generating plant alone amounts to about 0·06*d*. per unit, considerably more than wages and salaries, and more than half the cost of coal, and the rates on the cables bring the charge up to 0·1*d*. It is a tax or contribution towards local expenditure, which has grown to dimensions far greater than the early years of its operation seemed to indicate. Without demanding the complete abolition of rates on these public industries, some substantial reduction may be claimed, such as one-half, amounting to 0·05*d*. per unit. If to this is added the equal sum which the cheap fuel of the pit-head station can achieve, a total reduction of 0·1*d*. is obtained. The importance of this will now be discussed.

### Future Consumption

The cost for generation in large steam stations is 0·25*d*. per unit at the usual load factor of 0·4, while the selling price is at least 0·5*d*. for domestic heating, power being 0·75–1·0*d*., and lighting threepence to sixpence. Local rates account for some of this difference, but distribution and office expenses are the chief part. Both are nearly constant expenses for a given maximum demand, and are directly reduced by a high load factor. Also the cost is decreased by a greater density of load over an area. More consumers per mile of low-tension cable merely mean more feeding points and larger high-tension mains or a higher tension, and to obtain a more nearly universal demand and a larger demand per house is simply a matter of reduction of selling price, while they will themselves help greatly to reduce the cost further, if the process can once be started.

There are, as comparatively little developed directions for new demand, the fields of domestic heating of all kinds and electrification of railways. In these a successful competition with other methods depends largely on cost. Electric cooking, hot-water supply, and house-warming must be brought down to a figure not greatly exceeding that involved in the consumption of raw coal, if anything like a general adoption is to be brought about. A figure of one halfpenny begins to be persuasive, but above that the added convenience does not outweigh the cost in the view of most people, and even that figure only meets the competition of gas on equal terms, if the price of gas is eightpence per therm, and there are signs that this may be reduced. The possible demand is enormous, for the present consumption of domestic fuel is some forty million tons per annum, more than three times the whole of the coal used in electric supply for all purposes. Owing to the large losses of energy in the steam engine, with boiler losses and transmission, at the best only 20 per cent of the total heat in the coal burnt is delivered to the consumer. The domestic fireplace has a rather better efficiency, but it is not used so economically, so on the whole the amount of coal used will be much the same. The station uses a cheaper fuel, but loses on the cost of distribution. As domestic heating yields a high load factor, and offers scope for a high density factor, it will help greatly in lowering distribution costs.

The railways offer a large, though not so large, a field. This was explored by Lord Weir's committee of 1931, and the finding was favourable. The price of electric energy was taken at 0·5*d*. per unit, and at that figure the electric power came out at little less than the cost of present methods. Since then, locomotive designers have not been idle, and coal consumption has been reduced in the latest patterns, so that a substantial reduction on the halfpenny will be required. This should be quite possible, for the price that was assumed was

on the safe side and could be reduced to-day, and the further reductions indicated in this paper will bring the question to a practical proposition. The complete electrification was estimated to require a consumption of 5,400 million units, but probably a good many branch lines would not be electrified, and a total of 4,000 million may suffice. It is not a great addition to the total load, which was close on 16,000 millions last year, but it is a desirable increase, as it will have a good load factor and can be easily provided, for railways and population go together.

There are signs that a low price will bring in large consumers in the metallurgical industries. The use of electric furnaces is rapidly increasing, and below 0·5*d*. the private plant has little chance of competing, if complete reliability is to be ensured. The possible magnitude of this load it would be futile to estimate, but it will be considerable and will have an excellent load factor.

From the foregoing, it is evident that the electric supply industry can be put on the road to a substantial and even to a great increase, and that the new business will materially improve the load factor and reduce costs of distribution. The use of cheap fuel, and an alleviation of the burden of rates, will give the initial stimulus that is needed, and the great increase will automatically recoup the apparent loss to the rate fund of the local authorities.

To sum up the main theme, the Grid and the branch lines should operate not only as distributors of power to the consumer, wherever he may live, but also as collectors of power wherever it may be obtained, and like all successful middlemen, it should buy in the cheapest market and put the consumer into connexion with the nearest producer, whether small or large. The small producer, in other goods as well as electricity, may show very low costs of production, but fail to find a steady market. The Grid can offer such a market, and while it has no warehouse or other means of storage, it can harmonise the consumer and producer by varying the output of the large stations, which will work on the principle of keeping up the pressure at distribution centres, and the current will flow naturally to where it is demanded. The stations will gradually be placed where their costs are lowest, and the pit-heads and coal-cleaning floors will be their natural sites for the greater part of Great Britain. The economies thus made possible will attract consumers that are at present in doubt, and a great increase will ensue.

The question of the ownership of these large pit-head stations will require consideration. Several solutions are possible, but for all of them it is essential that there shall be co-operation between the producers of coal and the producers of electricity. The one party must be assured of a steady sale of their cheap fuel, that they may be willing to remodel their business to suit the new outlet; the other party must be assured of a steady low price, that they may not be exploited after they have given hostages by large expenditure on the new stations. It seems a suitable case for a central control, as without guarantees neither party would be wise to commit themselves, though the advantages to both seem fairly certain and considerable. A proposal of such wholesale common action would have seemed impracticable ten years ago; but we are becoming used to central boards, and the Coal Board and the Electricity Board are already in being for the purpose.

## Aberdeen Meeting of the British Association

NOW that the 1934 meeting of the Association has come and gone, it is possible to give some account of matters which were of general interest to the members. That it has been an unqualified success is the opinion of the chief officials of the Association, other members, and the public generally. The proceedings of the Association commenced with the president's address in the Capitol buildings on Wednesday evening, which upwards of 2,300 attended. The building provided was an ideal setting for a memorable opening address.

The two evening discourses were held in the MacRobert Hall, a building which holds about 800 persons, and on both occasions the Hall was well filled. The speakers were Sir Frank Smith, who delivered the Hardy Memorial Lecture, and Prof. W. L. Bragg, and the audience at the close showed their evident appreciation.

The attendance at sectional meetings was almost without exception good, and, in some cases, more persons wished to hear particular papers than could be accommodated comfortably. On the whole, the programmes provided in the sections appear to have satisfied the demands both of the more strictly scientific members and of the general public. The accommodation provided for the meetings of sections was in every way convenient and satisfactory, as also the arrangements for mid-day meals and other refreshments in proximity to the sectional meeting-places.

Most sections had a very full programme of excursions, of which every advantage was taken. Particular notice should be taken of the Telford Exhibition housed in proximity to the Engineering Section, which was so well patronised that it was arranged to continue the exhibition until the end of the second week. A practical demonstration on