HYDRO-ELECTRIC RESOURCES OF THE SCOTTISH HIGHLANDS.

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One of the most far-reaching effects of the recent Great War has been to bring the nation face to face with its own resources. For decades previously its chief concern had been the promotion of specialized industries in the large centres. Almost everything else was sacrificed to this national activity; and the lives of men were moulded to feed the fires and keep going in pitiless monotony the rattle of machinery, which was fast becoming an industrial Moloch. No doubt the age of coal and iron may have to be regarded as a necessary stage in the onward march or evolution of civilization. But we have only to visualize the effects as we know them, to realize how far a large proportion of the working classes have been side-tracked by this industrialism.

The wonderful thing is that we have hitherto been so blind with regard to our real assets. It is plain enough now that we have erred in two ways. On the one hand we have wasted most extravagantly many of our resources, and on the other hand we have almost entirely neglected others. To be economical was tantamount to being mean, for the more we wasted and destroyed the more it was thought we benefited the workman. Resources that could not compete with the great centralized industries, or ministered only to the æsthetic, the ethical, the moral or spiritual well-being of the population were more often quietly ignored. Only a feeble attempt was made to render them practically available.

In the midst of the great struggle we were forced by stern necessity to take stock of our resources in a way that the nation has never been called to employ before. As a result our eyes are now open to new possibilities and new potentialities. We think of agriculture and allotments, of afforestation, of man-power, of water-power, of the housing and health of the people, of transport, of education and many other things.

Of the various national resources to which the attention of the Government and of the people is now directed, water-power is dominant. Personally I am concerned with it not only as an industrial proposition but also as a means of elevating the national life, of restoring its man-power, of relieving the congestion in the large centres, of resettling the people on the land and of furnishing them with better houses, better food and clothing, and a more natural life in the country. In a word, I hold that the proper use of our water-power in the Scottish Highlands would go far to solve some of our pressing problems and promote comfort and contentment among large sections of the population. This healthy life of the country would react in a beneficial way upon the higher interest of the cities.

When we remember that the main sources of water-

power are the rivers and lochs and waterfalls in the Highlands, we realize at once their value towards those ends. In the past for several generations the Highlands have been pouring their best manhood and womanhood into the cities and towns; and the glens and straths have been becoming more and more desolate. Much of the land has been going out of cultivation and, like the hills and the moors, was being given over to deer and sheep. The nation as a whole came to regard the Highlands more as a preserve for sport, or as a summer resort.

We think of those splendid regiments who have fought for us with such distinction on the fields of Flanders and in the uttermost parts of the earth, bringing victory to our cause—the cause of right and freedom. We do not wish this race—these hardy sons of the mountain—to die out through their land becoming desolate. We want to keep them on the soil as far as is consistent with their own well-being, not only as a bulwark of our freedom, but, in the future, more especially to rejuvenate the life of the nation by infusing new blood and fresh ardour into the cities.

Then we know that these hills so silent and so stable are admirably adapted for afforestation. Thousands of acres of trees have been cut down on their slopes during the war, and thousands of trees are still being removed to supply the necessities of industry; so that the land in this respect is becoming depleted. There is need to make use on a much larger scale than ever of the hills and moors that were once the great Caledonian Forest chosen by Nature for tree and shrub.

A little industry introduced here and there throughout the Highlands to supplement the local activities and at the same time to utilize more fully the local resources, is what is needed. For this industry water-power is immediately available and it is so distributed by Nature that there need be no congestion as in the large centres, but it may be easily apportioned to serve wide areas over the land.

Villages which would be miniature garden cities would thus begin to spring up as marts and centres for the rural districts; and the housing problem which is now so urgent could in these parts be solved by laying out these villages on new lines, and erecting cottages with gardens, not more than six or eight to the acre.

Hitherto the Highlands have been severely handicapped in the matter of industrial activity through not having a coal supply of their own on an adequate scale. Now that the coal shortage and dearth of fuel for power purposes is acutely felt elsewhere as well as in the North, it is all the more important to turn to the bountiful provision of Nature whereby we are no longer dependent entirely on coal for power, but

may have our own railways and machinery worked by a more simple and, in the Highlands at least, more readily available natural resource. The extent of the Highlands is 40 per cent of that of Scotland, and only 7 per cent of the population is within that area. Newlands has said: "It is in territory such as this that a keen discriminating intellect is developed, and that the brawn and muscle of the British race is bred and reared, and not in congested hives of industry, and if employment can be found for such a people in their own environment it is all to the nation's interest to provide it."

On the 6th June, 1919, I read a paper before this Institution in Aberdeen on water-power, and I then summarized the natural sources of energy, as tides, food, fuel, wind and rain. I referred more especially to the first Interim Report of the Water Power Resources Committee dealing with nine possible water-power schemes in the Highlands capable of giving 183 500 (continuous) electrical horse-power, and the average estimated cost per electrical horse-power at the power house was £38·5. Since that date the Committee have issued a second, a third, and a final Report in 1921. The final Report is a voluminous volume and gives details of 39 schemes in the Scottish Highlands which, if developed, would yield 189 000 kW (continuous).

No. of Table	No. of Schemes	Kilowatts (continuous)
2	12	112 190
3	3	8 290
4	8	16 470
5	9	6 655
6	3	38 700
7	3	5 680
8	1	1 120

In addition to these schemes there is the Lochaber Water-Power Act, 1921, which provides for the production of 23 000 kW (continuous). Alternative and modified schemes are given in different appendixes by well-known engineers, and a study of these is recommended to anyone specially interested. The Committee very correctly state: "Remoteness from populated districts may be a factor facilitating the prospects of developing a particular water-power site, since under such conditions there are usually fewer interests to be conciliated, and, in consequence, the expenditure on compensation and rebuilding is likely to be comparatively small. In this respect, the conditions in the Highlands of Scotland are very favourable for water-power developments. The population is sparse in most of the areas in which water-power resources are situated. Yet, owing to the character of the coast line and the position of the Caledonian Canal, no water-power site is far removed from a point from which ready access to the sea is obtainable. The majority of the schemes communicated to us by the Board of Agriculture for Scotland are relatively small, but we understand that in most cases they are contiguous to

fishing centres or to railways where ready means of transport for manufactured articles can be obtained, and there is already in existence a local population from which labour could be obtained for industry.

"The Highlands are very sparsely populated and we understand that the generally prevailing low standard of comfort in the area is responsible for an abnormal amount of emigration which it is highly desirable to arrest. Generally speaking the land is poor and affords little promise of agricultural development, there are few minerals of value, and, apart from sheep rearing and what agriculture is practised, the population are dependent on the fishing industry, forestry and sport for a difficult existence. A main contributory factor to the emigration which takes place is the absence of social and domestic amenities. The development of water-power in the Highlands would tend to stop the tide of emigration, and would actually lead to immigration of labour from the Lowlands, and hence the growth of an industrial population would cause a demand for foodstuffs which would lead to an improvement in the pastoral agriculture of the adjoining areas."

The second Interim Report deals with the general nature of the machinery of control which is required in order that the water resources of Great Britain may be properly conserved and fully and systematically utilized for all purposes. The Committee say: "In the development of water-power both large and small, facilities must be given for private enterprise of different kinds as well as for public electricity supply. While there are localities where water-power will in the future be properly developed to assist the generation of electricity for public supply purposes, there will also be cases, especially in Scotland, where the geographical situation of the water-power will only permit of the full utilization if an industry is set up alongside, or in direct connection with the water-power station, e.g. the British Aluminium Company at Kinlochleven. In many cases the power to be developed may be small or remote from a public electricity supply system: in such cases private enterprise may be the only means of securing its development.

"The development of large water-power undertakings necessarily takes some years and during the constructional period capital is expended without any accruing revenue whatsoever. When once completed, however, the undertaking would be a valuable source of wealth, and it is important to remember that by far the largest portion of the total running costs is represented by interest and other charges upon the capital sunk in the undertaking. Private enterprise will need encouragement, especially in the Scottish Highlands, where the population is too sparse to allow an undertaking of this nature to be established through funds advanced by local authorities, to whom the large capital involved would be too great a burden to be practicable. It will, therefore, be necessary to assist some of the schemes out of national funds, the return on which should represent a sound investment for the State, and without which this valuable source of power would continue to be wasted."

I propose now to draw attention to some water-power schemes already in existence in the Scottish

Highlands and also to refer to some proposals that have materialized since 1919, when I read the paper to which I have referred.

The hydro-electric works at Foyers commenced operation in 1895, and the production of aluminium there was described in a paper* read by Mr. W. Murray Morrison before the Glasgow Local Section (now Scottish Centre) of this Institution on the 10th December, 1901, which paper should be referred to for details. The water is derived from the River Foyers which has a catchment area of upwards of 100 square miles. Two lochs have been joined together by dams and embankments so that the area is about three square miles, the storage being sufficient to give a continuous supply for about seven weeks. The head of water is 350 feet. Originally there were seven large Girard turbines built by Messrs. Escher, Wyss and Co., driving seven vertical direct-current low-pressure Oerlikon dynamos of 700 electrical horse-power each at 150 r.p.m. Mr. Morrison wrote to me quite recently: "The old plant is still doing very satisfactory duty, but some years ago two further units were added, being Pelton wheels by Escher, Wyss and Co., and generators by Dick, Kerr and Co.; also one smaller unit was added."

On the 14th November, 1911, a paper was read by Mr. Alfred Henry Roberts before the Institution of Civil Engineers on "The Loch Leven Water-Power Works," and on the same evening a paper on "The Hydro-Electric Plant in the British Aluminium Company's Factory at Kinlochleven," was read by Mr. Frederick Bolton Sonnenschein. These two papers and the discussion occupy 114 pages of the Proceedings and are well worth careful study by anyone interested in the subject. The company that obtained the Act of Parliament in 1901 was the Loch Leven Water & Electric Power Company, but the construction was deferred and in 1904 a revised scheme was submitted to Parliament and duly authorized. The factory work started in February 1909. The whole of the works are now the property of the British Aluminium Company. Mr. Roberts states the requisite features of a commercially successful water-power installation to be: (1) a large catchment area; (2) a heavy rainfall; (3) suitable sites for a storage reservoir, and for the construction of a dam; (4) a high fall to give a large head at the turbines; (5) suitable space for the construction of power house, factories and dwelling houses, at a low price for the land; (6) nearness to a large industrial centre—or to the open sea, if the power can be utilized on the spot for manufacturing purposes; and (7) suitable facilities for the provision of wharves, and protection for shipping in a natural or artificial harbour. A portion of Mr. Roberts's paper is devoted to prove that these advantages are all possessed in a remarkable degree by the Loch Leven water-power scheme. Mr. Sonnenschein's paper deals with the power plant and the generators.

Since the completion of the works as described in the above two papers important additions have been made. Mr. W. Murray Morrison, the General Manager of the British Aluminium Company, supplies me with the following information: "In the first

place there has been an extension of the water-collecting area by 6.1 square miles, arising out of the inclusion of Loch Eilde Mor and Loch Eilde Beag, together with the streams running into them. A dam has been constructed at the lower end of the former, and connection has been established between it and the main reservoir behind the Blackwater Dam by means of a reinforced concrete pipe about 5 miles long. At about two-thirds the distance between Loch Eilde Mor and the Blackwater Reservoir a side intake was constructed for the purpose of taking in the flow from the stream Allt Coire Na Duibh, the pipe diameter to this point being 48 inches and between the side intake and the Blackwater Reservoir 54 inches. A discharge chamber was constructed at the outlet with measuring weir fitted with the requisite apparatus for enabling a continuous record to be kept of the flow.

"The work was carried out to the designs of Mr. C. S. Meik, under the direct supervision of the late Mr. Bryce Johnston. The contractors were Messrs. Balfour Beattie and Co., Mr. Pitcairn acting as their agent. It was commenced in the beginning of 1916 and was sufficiently completed by January 1918 to enable water to be taken in at the side stream intake. The work was fully completed and water was flowing through from Loch Eilde Mor by the end of July 1918. Owing to the extreme importance of increasing the output of aluminium during the war, the Government arranged for the supply of about 1 000 German prisoners of war to assist in carrying out the work.

"In order that the fullest use might be made of the additional water supply from the above source, it was decided that the main dam at the Blackwater Reservoir should be increased in height to the extent of 3 feet. This has the effect of providing additional accommodation for 260 million cubic feet of water, making a total of 3 320 million cubic feet, which is sufficient to maintain the whole of the plant in operation for a period of about three months.

"The plant as installed originally in the power house consisted of nine sets each of 2 000 kW capacity, which together with the auxiliary generating sets for traction and lighting gave a total plant capacity of 19 150 kW. An additional set of 2 000 kW was installed in 1914, consisting of a turbine by Messrs. Escher, Wyss and Co., of the same design as the original plant except that it is fitted with deflectors to each of the nozzles in place of the by-pass arrangement for obviating any sudden increase in pressure in the pipes on the sharp reduction of the load. Further, the needles are operated by the governors by means of an oil pressure regulator. The direct-current generators are of similar type to the original plant and were supplied by Messrs. Dick, Kerr and Co.

"In view of the additional water available from Loch Eilde Mor, a further 2 000-kW generating set was ordered and installed in 1918. This consists of a turbine of the Pelton wheel type supplied by Messrs. James Gordon and Co. It differs from those supplied by Messrs. Escher, Wyss and Co. in that it is fitted with one nozzle only. The governor and needle gear is of the oil-operated type, and a deflector which is fitted to the nozzle comes into operation with sudden variations

* *Journal I.E.E.*, 1902, vol. 31, p. 400.

of load so as to prevent heavy increase in the pressure in the pipes, which would arise if the needle gear were arranged to close quickly. The generators are identical with those previously installed. The total plant capacity is now 23 150 kW for continuous running, with an overload capacity of 25 500 kW. Considerable extensions to the reduction furnace plant were made, and, in order to meet the increased demand for carbon electrodes arising out of the increase in the aluminium reduction plant, extensive additions have been made to the carbon factory; not only did these enable the Company to maintain their own works in operation but they were at the request of the Government, during the war, called upon to supply a very large quantity of electrodes for shipment abroad to works under the control of the Allies.

"Arising out of the increase in output generally, and particularly out of the necessity of employing women during the war, the Company have had to carry out considerable extensions in the way of housing accommodation, inclusive of the erection of three hostels, each of which accommodates 100 persons, and is self-contained in that it has its own kitchen, dining and recreation room, baths, etc.

"In view of the very great importance during the war of maintaining the maximum output of aluminium, the Government decided to proceed with the long-talked-of road between Ballachulish and Kinlochleven, so as to afford further means of communication beyond that already existing by sea. The work was originally put in hand with the labour of conscientious objectors, but later these were replaced by German prisoners of war. The work was therefore interrupted by the Armistice, and has only been carried on slowly since then by the local road authorities. It is, however, now practically completed and has been opened for traffic.

"It is interesting to note that the maximum possible output of aluminium was maintained without interruption throughout the war, when it was, of course, of the utmost importance that the largest possible quantity should be placed at the disposal of the authorities.

"During the past 12 months the universal depression in the metal and most other industries has necessitated the temporary closing down of a considerable amount of the plant, but recently some of the plant was restarted and the works are now operating at nearly full load."

I shall now summarize two proposed hydro-electric schemes, namely, the Lochaber Power Scheme and the Grampian Power Scheme.

The catchment area of the Lochaber water-power scheme, promoted by the British Aluminium Company for the development of which an Act of Parliament was obtained last year, is 303 square miles. Taking the average rainfall as 73 inches this gives 1 056 million gallons per year per square mile, and therefore for the whole area 876 million gallons per day. The average head of water available near Fort William is 742 feet, so that the theoretical horse-power is 137 300. The Company estimates 72 000 to 75 000 horse-power (continuous) which gives as their estimated efficiency about 60 per cent, but they anticipate that 100 000 h.p.

will be obtained in all but the drier years. Now, 1 h.p.-year is equivalent to 6 535 kWh and to 10 tons of coal. Thus the Lochaber water-power scheme would result in a saving of $\frac{3}{4}$ million to 1 million tons of coal per year. Of the total generated a minimum of 5 000 h.p. has been reserved under the terms of the Act for other industrial consumers. The proposal is to form a weir just below the confluence of the River Spey and the Markie Burn, about $2\frac{1}{2}$ miles to the westward of Laggan Bridge in Inverness-shire. During floods the level of the Spey at the point would be raised by some 30 feet, so that a small reservoir about 2 miles long and just under $\frac{1}{2}$ mile in its widest part will be formed. A great deal of discussion took place before the Select Committee of the House of Commons on this part of the scheme, as to its effect on the fishing of the Spey. The Spey Fishery Board wanted 100 million gallons a day as a minimum flow and refused an offer of 45 million by the promoters. The Committee by way of a compromise decided: (1) that the water of the Upper Spey above the upper intake is not to be abstracted up to a flow of 30 million gallons per day; (2) that the Spey Fishery Board shall have the right to demand that in 12 days of the year (not necessarily consecutive) water shall not be abstracted until the natural flow of the river reaches 100 million gallons per day; and (3) that the conduit at the intake of Loch Laggan shall be increased by 75 per cent. When the Committee met two days afterwards to adjust clauses it was intimated that the Spey Fishery Board after consideration preferred to have a flow of 40 million gallons per day all the year round on such days as the flow of the river allowed it.

The water so derived from the Spey is to be led through a conduit nearly 3 miles long to make a junction with the River Pattack near the point where it turns westward to flow into Loch Laggan, the difference of level being from 860 feet above ordnance datum to 840 feet. A dam is to be constructed on the River Spean about $3\frac{1}{2}$ miles from the outlet at Loch Laggan, with the result that the loch will be lengthened from 7 to $10\frac{1}{2}$ miles and this is to be called the Spean Reservoir. A tunnel $3\frac{3}{4}$ miles long connects the reservoir with Loch Treig, whose level is to be raised 36 feet or 1 foot lower than the top water level of Loch Laggan. The power house is situated on the banks of the River Lochy just above Fort William, and the tunnel connecting it with Loch Treig is to be no less than 15 miles in length. The waters of 14 streams are to be tapped on the way by vertical shafts varying in depth from 175 feet to 350 feet. A description with a map and a section appeared in the *Engineer* of 4th March, 1921, and for further details I would refer those interested to that article.

One of the most interesting paragraphs in the above-mentioned article is that referring to the tunnel from Loch Treig: "Loch Treig, which is rather over 5 miles long and $\frac{5}{8}$ mile wide in its widest part, has a normal level at the present time of 783 feet above ordnance datum, that is to say 37 feet below the top water level of Loch Laggan. It is proposed, however, to raise its level to 819 feet above ordnance datum, or 1 foot below the top level of Loch Laggan, by means of a dam. It will thus be observed that the water coming down from the Rivers Spey and Mashie, the Markie Burn,

Loch Laggan, and the Spean Reservoir, will gravitate into Loch Treig, which will, in fact, act as a fore bay of the power house, for the water from it will be continuously under pressure until it issues from the turbines. It is a deep loch having a maximum depth of some 436 feet, and one of the most interesting features of the whole undertaking is that, by means of a tunnel, it is proposed to place the invert of the outlet at 680 feet above ordnance datum, or no less than 139 feet below the raised top water level of the Loch. At present no details of how the work of driving the tunnel into the Loch is to be carried out have been made public, but it will be an interesting operation."

Mr. Morrison in giving evidence before the Select Committee stated that it was the policy of the Company to employ local labour as far as possible, and they had supplied satisfactory accommodation for their workers. He said: "If the present scheme is sanctioned the Company will be able to employ nearly 3 000 additional hands. Last year they paid £170 000 in wages at their factories at Foyers and Kinlochleven. Of the employees 80 per cent are Highlanders and Islanders. The construction work of the new scheme, if authorized, will occupy about 5 years, and during that time will provide employment for several thousand men."

The Grampian Water Power Scheme of 1921, which conflicted with the Lochaber Scheme, especially as to the utilization of the water of Loch Pattack, was withdrawn. This year a modified scheme has been passed recently by a Select Committee of the House of Commons. The promoters are the Hydro-Electric Development Company and they aim at supplying electricity for all purposes in the counties of Perth, Kinross and Forfar, and the parishes of Kingussie, Insh, Laggan, in Inverness-shire; Lismore and Appin in Argyllshire; and Buchanan, Drymen, Killearn, Balfour, Kippen, Fintry and Gargunnoch in Stirlingshire. Over 50 lochs, rivers and streams are involved in the scheme, but the chief ones are Lochs Ericht, Rannoch and Garry, the River Garry, Loch-an-Seilich, Loch-an-Ruin, the Truim, Bruar River and the Mhaire Water.

The catchment area is 417 square miles and the proposed four power houses can give out 56 000 h.p. continuously, as follows: Tummel 17 400, Garry River 7 500, Bruar River 4 200, and Loch Rannoch 26 900. The power house at Loch Rannoch is to be supplied by a tunnel from Loch Ericht which is to be raised in level by 37 feet. The storage capacity of Loch Ericht will be 80 000 million gallons, of Loch Garry 410 million cubic feet, and of Loch Rannoch 1 600 million cubic feet or 10 000 million gallons. The first part of the scheme, beginning with the Tummel, would cost £2 603 000, and the whole scheme 4½ million pounds. It was stated in evidence that on the completion of the first stage, if a sale of 170 million kWh per annum were assumed, the cost per unit would be 3½d.

There was considerable discussion about the financial arrangements, and Mr. Briggs, M.P., a member of the Select Committee, expressed the view that the project was of a highly speculative nature and one in which Government money should not be invested. On the 11th May he asked the Chancellor of the Exchequer in the House of Commons: "If he is aware

that the promoters of the Grampian Electric Supply Bill have received a letter, dated 20th April, 1922, from the Secretary of the Trades Facilities Act Committee, stating that, subject to the approval of the Electricity Commissioners, the Committee would be prepared to recommend a guarantee of both Capital and Interest of the Debenture issue of the Company equal in amount to the Ordinary Share Capital of the Company, and if he is satisfied that the Commercial future of this Company warrants the use of public money to guarantee Capital and Interest to such a proportion of Debenture issue."

The Chancellor of the Exchequer replied that he proposed to be guided in the guarantees given under the Act solely by the advice of the Trade Facilities Advisory Committee, which consists of three business men of great experience and ability. At the third reading of the Bill on 23rd May there was a motion for its rejection which was defeated by 185 votes to 78.

The City of Dundee has increasing demands on its electrical station, and the Corporation had in view a possibility of buying electricity in bulk from the Grampian Company provided an adequate supply at a low cost could be guaranteed. Failing satisfactory guarantees as to the amount and continuity of the supply of current by the Company, Dundee had in contemplation a scheme of their own, but as they included the utilization of Lochs Ericht and Rannoch, now granted to the Grampian Company, I need not give details. Dundee withdrew its opposition to the Grampian Scheme, provided that the Company undertook not to run their cable through Dundee, and that permission for electrified construction should be limited to main-line electrification of railways only. Also, by a majority the Dundee Committee decided to enter into an arrangement with the Company if the price of electricity be reduced to £3 per annum per kilowatt of maximum demand, and ½d. per kilowatt-hour, provided that the Company paid the standing charges, plus a fixed annual rental of £5 000 in respect of the Corporation's electrical station, and provided also that the other conditions of the agreement should be satisfactorily adjusted between the Corporation and the Company.

The Electrical Engineer of Dundee has recently written me to the effect that: "As regards the supply of power to Dundee by the Grampian Company, as they have had to admit that they are unable to compete with the present thermal system in Dundee the only possible hope is a combination of the hydro-electric stations with my present steam stations. Such a combination is able to show, on paper at any rate, a possible small saving in years to come so far as Dundee is concerned. Future saving, however, depends so much upon the possible cost of coal that it is very difficult for the Council to decide to give up control of its own generating station. There is a section who believe that the cost of coal will go up, and in any case labour troubles will never cease, so there is an advantage in favour of water power with its comparative independence of labour disputes. In short, Dundee is prepared to buy as soon as anyone has current to sell—at a price."

I shall now describe two small water-power schemes making use of the water of streams without reservoir or batteries. The electricity generated is utilized in

lighting and heating mansion houses and driving electric motors for farming purposes.

The first is at Inshes. This hydro-electric installation is very interesting as it shows the possibility of harnessing the water power of small streams in the North of Scotland, and there are hundreds of such streams. The scheme was prepared and carried out by Mr. E. J. Williams, Scottish Manager for Messrs. Edmundson's Electricity Corporation. The estate concerned lies $2\frac{1}{2}$ miles to the south-west of Inverness. There the River Millburn, about $2\frac{1}{2}$ miles in length, owes its present name to the fact that in quite recent times meal mills driven by water power were quite common in the Highlands and there were no less than six such mills on this stream. The total output of these water-power meal mills, four of them of the overshot type, was 40 h.p. The average flow of the river is about 120 cubic feet per minute and the minimum within recent years 90 cubic feet per minute, though during last year's drought it dropped to 50 cubic feet.

At the power house there is installed a "Turgo" impulse turbine by Messrs. Gilbert Gilkes & Co., of Kendal. The gross head of water is 320 feet. It was found that with a head of 310 feet and a flow of 96 cubic feet per minute the output of the turbine was 34 h.p., and the overall efficiency (including 9.7 feet as the loss due to friction head) was 60 per cent. When the flow was 224 cubic feet per minute the output was 88.3 h.p. and the overall efficiency (including 53 feet as the loss due to friction head) was 67.4 per cent. Coupled to either side of the turbine is a compound-wound generator of 22 kW capacity. The installation in Inshes House, 1 000 yards distant, consists of 150 30-watt lamps for lighting, a few heaters, a hot-plate in the dining room, and a washing machine and irons in the laundry. The power house is connected to the Inverness town network by a pole line $1\frac{1}{4}$ miles in length. Mr. Williams, writing in the *Electrical Review* in December 1920 two months after starting, said: "The supply from the scheme has enabled the Inverness local electricity works to dispense with a Sunday morning shift of two men, and it has also reduced the running hours of the steam plant by at least one hour per day, it being possible to start up half an hour later in the morning, and shut down at least half an hour earlier at night." Writing to me quite lately he says: "With regard to the Inshes scheme, I may say that now there are five farms and seven large houses connected to it, and that in each of the farms beside the lighting there are motors. The lines are at present being extended to the village of Culcabok where it is intended to give the villagers a supply at a fixed charge per lamp per annum. The surplus current which is fed into the town network is quite as much as estimated, and for the year now just completed this amounted to 95 000 units. The current used locally by the farms amounted to a further 14 000 units. The scheme has in every way come up to expectation, and has aroused a good deal of interest in the North."

Messrs. Allan Arthur and Ure, Glasgow, have supplied me with information about a water-power plant which they designed and installed during 1921 near the head of one of the sea lochs in Argyllshire. The catchment

area of the stream from which the power is derived is about 2 square miles, with hills rising on either side to over 3 000 ft. It was found that the minimum flow after 6 weeks' drought was 50 cubic feet of water per minute, and the maximum 20 times this. Hence it was decided not to build a reservoir but to build a substantial concrete weir across the stream at a level 290 feet above the turbine house, which would act as an intake. The pipe line, which is about 2 000 feet long, is carried underground to the turbine house situated on the bank of the stream and at a distance of about 50 yards from the dwelling houses, to which the cables are led underground.

The turbine, which is of Messrs. Gilbert Gilkes and Co.'s make, is capable of giving 33 b.h.p. or 22 kW at full load at about 650 r.p.m. and of passing 85 cubic feet per minute. The dynamo which is direct coupled to, and on the same bedplate as, the turbine is of Messrs. Horace Green and Co.'s make, compound-wound and designed to give 85 amperes and 270 volts at 650 r.p.m. The plant runs continuously night and day, and no batteries are installed. In the mansion house there are over 100 lamps and plugs for lighting, while in the kitchen there is a cooking range consisting of two ovens, hot cupboard, grill and six boiling rings, the total loading being 13.6 kW. The hot water supply for the house is obtained from an electrically heated 45-gallon tank. Four electrical elements are fitted in this, each loaded to $1\frac{1}{2}$ kW, the temperature being automatically controlled at any setting desired, by means of a thermostat.

The whole scheme is designed for lighting, cooking, hot water heating, heating and drying by electricity, and thus 50 to 60 tons of coal are saved annually, as well as the expense and inconvenience of carting it for many miles to the house. Should additional heating be required, wood is burned in the fireplace. On the estate there is an abundance of wood which is cut up by a 36-inch saw driven by a 12-h.p. motor at times of light load on the turbine. The installation has been running with complete satisfaction for 18 months, the only expense being a few pounds for lubricating oil and replaced elements.

There are scores of similar Highland streams running to waste through sparsely inhabited glens and straths, which could be utilized for industrial and other useful purposes at comparatively small expense. The rainfall varies at different parts of the Highlands, but it may be taken that every square mile of catchment area, even in summer, will give an average flow of 180 cubic feet per minute or one electrical horse-power at 75 per cent efficiency for every 3.9 feet of fall. Thus there exists in the Highlands in our lochs and rivers considerably over half a million potential horse-power which should at once be utilized in establishing suitable industries in the places where the power is available.

We are now at a point of departure in our whole industrial system. The old order, black and barbaric in many features, is yielding place to new methods. The handicaps of the present time are so ominous and clog the machinery of life so much that the spirit of man struggles to be free, and in so struggling the mind of man finds out many inventions. We are thus in

the midst of readjustments which herald the dawn of a new era—a better time for the world—and it is given to us to be pioneers in the process. We cannot forget that for all practicable purposes, light, heat and power are coming more and more to be comprehended in the word “Electricity,” and, as our coal resources are being depleted, we must rely for its production in the future to a far greater extent on oil and water-power, and other at present undeveloped agencies. The oil and the water-power are already within our grasp, waiting to be used.

The practical part is a problem of intense interest to us as electrical engineers, but beyond the industrial and commercial I think we may all claim to have some interest in the moral and spiritual aspects of the question. At the best, getting coal in the bowels of the earth in

the dark, damp, cramped and often nauseous conditions obtaining there, is not exactly an ideal way of making men. It is barbarous and unnatural, though now so utterly essential to us. In the future—and may it be the near future—I fancy people will wonder at the black age, at the black hands and faces and clothing of men and boys emerging from the pits. If these conditions fail to develop the best in man, if they lead, as we suspect they do, to a moral obliquity or even moral blindness, can we wonder? Therefore, in developing the resources of Nature, such as oil, water-power and electricity, we are helping to clean and brighten the lives of thousands of men, and to deliver them from the grinding care and the black misery of the nether regions, thus raising them to a higher level of health and happiness and a higher ideal of manhood.