The Transactions of the South African Institute of Electrical Engineers

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Volume 45 AUGUST 1954 Part 8

PROCEEDINGS AT THE FOUR HUNDRED AND FORTY-SEVENTH GENERAL MEETING

Twenty-fourth Annual Joint Meeting with the University of the Witwatersrand, held at the University, Milner Park, Johannesburg.

Thursday, 26th August 1954

J. P. Anderson (President) was in the Chair and there were present 140 members and visitors and the Secretary.

The President pointed out that at this Annual Joint Meeting of the University of the Witwatersrand and the South African Institute of Electrical Engineers the fourth Bernard Price Memorial Lecture would be delivered. He then asked Mr W. Grant Mackenzie to open the meeting.

Mr W. Grant Mackenzie: Mr President, I have to open my remarks by conveying to you apologies from both the Principal, who is leaving for Canada to-morrow, and the Vice-Principal who, unfortunately, is not at all well.

Because of their absence, however, I am privileged to be here and to welcome you, Mr President, and all of you present, to the University to-night.

I understand that it was sometime during the 1930's when it was first suggested that combined meetings should take place between your Institute and the University. Other Institutes have also started such meetings which means that, for nearly a quarter of a century, our University has had the happy and stimulating advantage of these meetings. While I assume that your Institute has obtained some benefit from such gatherings, I would assure you that our University has benefited very much more.

To-night's meeting is the fourth of the Bernard Price Memorial Lectures, the first having been given three years ago, in 1951, by Dr Schonland whom I am very glad to see is present to-night. These Memorial Lectures were started by your Institute in memory of that grand gentleman Dr Bernard Price and it has become the custom to make these lectures the subject of such combined meetings as to-night—a further privilege of which our University is very conscious.

Your President will, I know, introduce to you Professor Meek who will deliver to-night's lecture but, from the point of view of our University, I would like to mention that Professor Meek is in Johannesburg as the guest of the Visiting Lecturers' Trust Fund, a commendable organization conducted by the students of our University. While we are all privileged to have Professor Meek here to-night, we, as a University, like to think that he is a guest of the students of this University.

There is a lot I could say but there is also a great deal to be done and said to-night. However, I cannot finish without mentioning that, as Chairman of our University's Finance Committee, and as Chairman of the Appeal Committee, and mentioning with a great depth of sincerity, how deeply and warmly grateful we are to the President and members of the Institute for not only your moral support but the extremely important financial support our University Appeal Fund has received from the Institute. I thank you all very much indeed.

The President, in thanking Mr Mackenzie, said the Institute valued the co-operation it received from the University and in this connection he would like to take the opportunity of thanking the University for allowing Professor Bozzoli to take his place, at short notice, to attend the meeting of the Commonwealth Engineering Institutions in London and the Eusec meeting at Brussels. He was also indebted to Professor Bozzoli in this matter.

MINUTES

The minutes of the monthly general meeting held on the 22nd July 1954, were taken as read, and confirmed.

MEMBERSHIP

The Secretary announced that in terms of By-Law 5.2.3, the Council had elected the undermentioned candidates to membership of the Institute in the following grades :—

Associate Members : Johann Lodewyk Naude Besseling, Cyril Owen Higgo, Kenneth Gordon Johnstone, Kazimierz Palczewski, David Rae Parker, Edward Wynn Summerson.

Associates : Julius Henry Davids, Reginald Leonard Reeves.

Students : Henry John Bessinger, John Edward Hardy, C. J. Veldman.

Transfer from Graduate to Associate Member : Frank Clare John Moon, Morris Ringer, Kenneth Stevenson.

ADDRESS

The President : We now come to the important event of the evening, the delivery of the Fourth Bernard Price Memorial Lecture.

We are indeed fortunate to be able to call upon Professor Meek to deliver this lecture on the subject of 'High-voltage spark discharges.' This is an especially apt title when we remember the work of the great engineer whose memory these lectures perpetuate.

Professor Meek graduated at Liverpool University in 1934, he then joined Messrs Metropolitan-Vickers as a college apprentice, subsequently being engaged in the High-Voltage Laboratory. During his sojourn with this concern he was granted two years leave to spend as a Commonwealth Fellow in the Physics Department of the University of California. Since 1946 he has been Professor of Electrical Engineering at the Liverpool University.

Incidentally, he is the joint author of three books, namely :—

(1) The Mechanism of the Electric Spark.

(2) Electrical Breakdown of Gases.

(3) High Voltage Laboratory Technique.

The President then introduced Professor J. M. Meek and asked him to deliver the fourth Bernard Price Memorial Lecture entitled 'High-voltage spark discharges.'

Professor G. R. Bozzoli (Vice-President) proposed the vote of thanks which was seconded by I. de Villiers (Vice-President).

The vote of thanks was accorded with acclamation.

The President declared the meeting closed at 9.25 p.m.

Editor's Note.—Professor Meek's lecture together with the vote of thanks will be published in the December 1954 *issue of the* Transactions.

THE ELECTRICITY SUPPLY INDUSTRY IN GREAT BRITAIN

By Sir John Hacking, M.I.E.E.

Address and discussion at a General Meeting of the Cape Western Local Centre, held in Electricity House, Strand Street, Cape Town, on Thursday, 22nd April 1954.

I am glad to have the opportunity of meeting here not only the Cape Town Branch of the South African Institute of Electrical Engineers but also members of my own institution, the Institution of Electrical Engineers, London.

At this meeting I have undertaken to talk about the electricity supply industry in Great Britain, and I propose to deal more particularly with the generation aspect with which I have been specially concerned.

I would like first to emphasize certain fundamental differences between conditions in Britain and South Africa. In Britain the centres of population and of load are relatively close together in comparison with this country. It is therefore relatively easy and economical to provide interconnections between those groups which enable a substantial reduction in spare plant to be achieved.

The second major difference is in the level of fuel costs. In Britain for the year ended December 1952, the pithead prices of coal for electricity generation were 46s. 2d. per ton, that is per ton of coal rather less than 11 000 B.T.U.'s per lb. That compares with the figure in South Africa of about 9s. The delivered cost of coal to power stations in Britain in that same year averaged over the whole country just over 60s. per ton. In South Africa, the highest cost is probably in Cape Town where the comparative figure is 40s. There is therefore greater incentive in Britain to strive for higher efficiency of generation.

Now with those preliminary remarks I would like to draw attention to one or two cardinal points in the history of Electricity Supply in Britain.

DEMAND FOR LOAD

Fig. 1 shows from the year 1920 to 1952 the growth in output of electrical units year by year. You will see that between 1920 and 1952 units sold have increased from 4 000 million to 53 000 million.

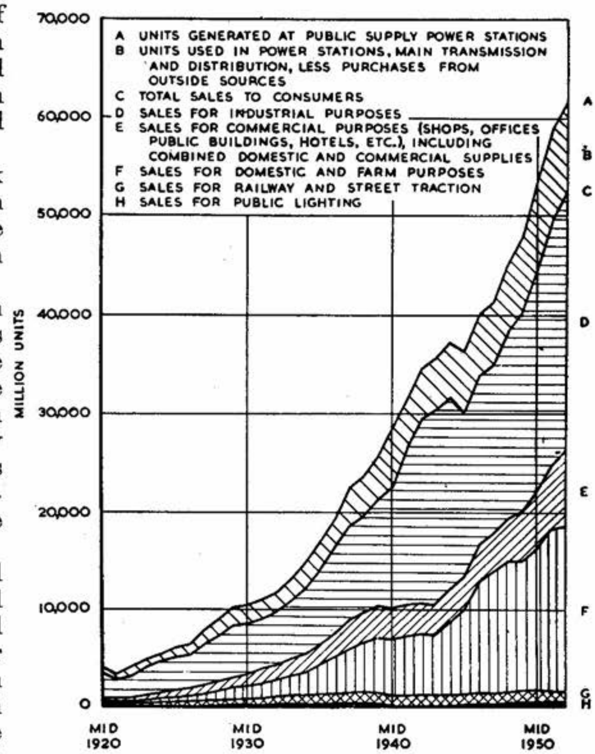


Fig. 1

We are often asked whether this spectacular increase is likely to continue. I do not think we are within striking distance of reaching the saturation point. At the present time in Britain the average consumption per head of population is 1 100 units per annum. In the United States of America the corresponding figure is well over twice the figure in Britain and yet in the United States the growth for which they are providing additional generating plant is of the same order of percentage as it is in Great Britain.

PLANNING PROCEDURE

To meet this large growth of demand it is, of course, necessary to plan generating plant programmes well in advance and you may be interested to know what is the practice in Britain. It is our experience that five years are needed from the time the decision is taken to build a power station to the time the first generator in the station comes into commission. Much preliminary investigation has to be done before we are in a position to start to decide to build a station on a particular site and a further two years is allowed for this. We have to consult defence committees, town-planning authorities, the owners and tenants of land in the neighbourhood of power stations, the National Coal Board in regard to the sources of coal for each particular station, the railway authorities in regard to the transport of coal and last, but not least, the River and other water Authorities in regard to the condensing water which is required for the station.

In the long run we have to obtain the consent of the Minister of Fuel and Power before we can proceed with work on that station. The Minister of Fuel and Power, after hearing the various objections, for which you will gather from what I have said plenty of time has been given, can, if he thinks that the weight of opposition is strong, decide that we should have a public enquiry before we can start to proceed with the construction of that power station. For such an enquiry evidence has to be prepared very carefully and quite a considerable time, probably five or six months, is taken in getting to the stage of having that enquiry after the Minister has decided it should be held. We are frequently, after an enquiry, kept waiting for some months before a decision is reached. You will see, therefore, that two years is not too long to allow for these preliminary stages. In March this year the British Electricity Authority, for instance, adopted a definite programme for plant commissioning for the year 1958, that is five years ahead, a provisional programme for the year 1959, and a tentative programme for the year 1960, and the work will already have been commenced in obtaining those various consents even for the tentative programme up to the year 1960, which is seven years ahead.

Fig. 2 shows the rate of commissioning of new plant in Great Britain from the year 1935. You will see that before the war our maximum yearly commissioning rate was 750 000 kW, and there was a great fall during the war years. That was because during the war practically no new programmes were initiated. With some exceptions the programmes which were in hand at the beginning of the war were allowed to continue, and you will see the gradual fall in plant installation which took place during that time.

In 1944, it was quite obvious to the Central Electricity Board that we were going to be in great difficulty in meeting the load situation immediately after the war and an approach was made to the Government just to warn them that if they did not allow us to initiate construction programmes during the war there would be a great shortage of plant after the war. The Government decided, I have no doubt quite rightly having regard to the facts at the time, that they were not prepared to devote any manufacturing resources to any purpose not definitely required to promote the successful termination of the war, and they refused their consent to any such programmes, at the same time giving us absolution on paper for any consequences which might flow. As a

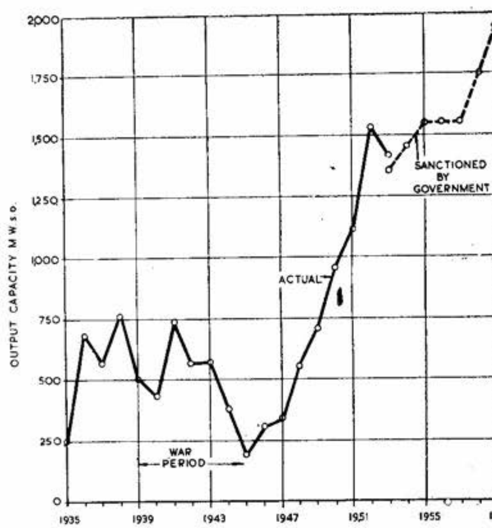


Fig. 2

result at the end of the war we had, if I may put it this way, practically no plant in the pipeline between the manufacturers' works and the sites. Further the manufacturers' efforts had been diverted to direct war purposes and considerable re-organization was necessary to get back on to a normal peace-time production. The Central Electricity Board at the same time felt doubt as to whether the manufacturers had sufficient capacity to meet the probable requirements. In order to test that they prepared tentative global plant programmes to meet loads which they estimated might occur during the next fifteen years. This indicated that the programme which was required would average at least 1 500 megawatts a year, that is more than twice the figure which had ever been achieved in Britain before the war, and we brought these figures to the notice of the manufacturers, drawing their attention, not only to the magnitude of the programmes envisaged, but also to the fact that programmes of that size would go on for a very long time, and we asked whether they were satisfied that they had the manufacturing resources to deal with them. We felt that we had given them sufficient assurances to justify any extensions in plant which they deemed to be desirable, and indeed British manufacturers did extend their works very considerably. If I might hazard a guess I should say that British manufacturers probably spent 20 or 30 million pounds in extending their works to increase their plant capacity, and you will see from the continuation of that curve how the plant installation grew until in the year 1952 we did reach a record figure of 1 536 megawatts of plant in commission. In 1953 there was a slight falling off. This was due to the fact that two years previously there had been a great shortage of reinforcing rods for foundations on account of the armament programme which held up our foundation work and naturally we didn't reap the full disadvantage of that for some two years, and the commissioning this year, I think, will not show a great deal of improvement over last year. Nevertheless I am confident that we can achieve and exceed the programmes which are shown at the end of that curve marked 'Sanctioned by Government.'

In spite of this large commissioning of plant, and arising from the factors I have already mentioned, we have had great shortages of plant during the immediate post-war years. Fig. 3 indicates the surplus and shortages which actually occurred in each of the succeeding years. You see in 1945/46 we actually had a surplus of some 400 000 kW. The winter was relatively mild and industry was not fully re-organized after the war. In 1946/47 we had a deficit of some 600 000 kW. In 1947/48 we had a grave coal shortage and following that we initiated with industry a programme of load spreading to reduce the peak loads. In spite of that the actual plant

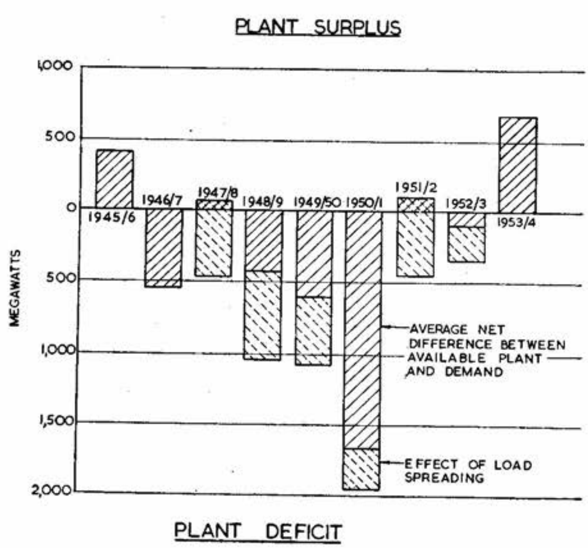


Fig. 3

shortage in each year grew until in 1950/51 we had an actual shortage of some 1 700 megawatts. That shortage might have been very much worse if the weather had been less favourable. We estimated that our potential shortage was of the order of at least 2 500 megawatts. In 1951/52 the position improved, but we avoided an actual shortage of plant only by the load-spreading arrangements which we had in force. In 1953 we were still better and we abandoned the load-spreading arrangements. In 1953/54 we had a quite satisfactory margin in fact for conditions as they existed then. Since then we have had, to all intents and purposes, no load shedding by physical disconnection, but we have had on occasions load shedding by voltage reduction and frequency reduction. We are not yet out of the wood, and in bad weather we still might be in trouble, but we are now installing plant at a materially greater rate than the growth of demand.

To complete the background I just want to refer to the Grid and the so-called Super Grid. You know that one of the first things the Central Electricity Board did was to create a 132-kV grid over the whole country. That grid interconnected the major sources of generation and the major load areas and did effect considerable savings in capital cost by pooling the spare generating plant. It did in addition enable a substantial measure of economy to be made by concentrating generation on the cheaper generation areas and the cheaper coal areas. The 132-kV grid was planned on a regional basis, each region being more or less self-contained and with only light emergency interconnectors between them. There is no doubt that further substantial economies can be made by more

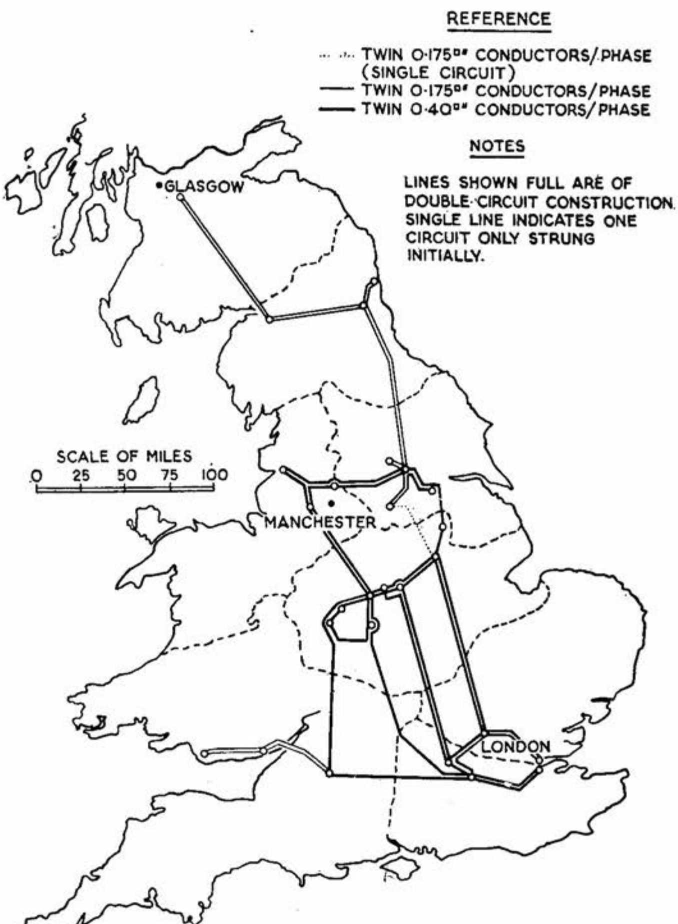


Fig. 4

substantial interconnection on a national scale. After investigating the matter and after considering the possibility of substantial reinforcement of the 132-kV system as an alternative to a higher-voltage system, we came to the conclusion that the most economical arrangement was to go to a 275-kV system and Fig. 4 shows the 275-kV system which is proposed.

You will see that in the Northern half there will be a double-circuit line from Glasgow to the Midlands which is shown in relatively faint lines. On that section each phase consists of two steel-cored aluminium conductors in parallel each with an equivalent copper section of 0·175 sq.in. The capacity of each circuit will be approximately 375 MVA. In the Midlands and the South each of the two conductors per phase has an equivalent copper section of 0·4 sq.in. with a capacity of some 575 megawatts per circuit. One exception to that is a single-circuit line shown just to the right of Manchester in a light line. That is an experimental 275-kV line which was initiated by the Central Electricity Board before vesting date and is a single-circuit line. That line is now in commission at 275 kV. A substantial part of the other lines shown there will come into commission in 1955 and we expect to have the whole of it in commission by 1960.

I have mentioned that one of the advantages of interconnection apart from the pooling of spare generating plant is the facility it gives within the capacity of that interconnection for concentrating generation on the cheaper-coal areas. In this scheme we are going beyond that. We are informed by the National Coal Board that a great deal of the additional coal requirements of the supply industry will be met from the East Midlands Coalfield, and we are therefore adopting the policy of concentrating base load generation on the rivers of the Midlands, particularly the River Trent which is reasonably close to that East Midlands Coalfield. These stations and the Southern section of the 275-kV system will be operated at high load factor so that stations in the South will be operated more as peak-load stations than base-load stations. We are aiming at off peak-load periods to transmit from the Midlands to the South something like 2 million kW and even at peak periods to transmit something like 1 million kW.

NEW PLANT

I would like now to turn to the main features of the new generating plant. Shortly after the war we adopted two standard sizes of generator for future programmes—30 megawatts with steam conditions of 600 lb per sq.in. and 850°F, and 60 megawatt with steam conditions of 900 lb per sq.in. and 900°F. I may say the decision to adopt the latter size was taken only after very careful consideration. There were certain countries which were going ahead with much higher pressures and somewhat higher temperatures, and we examined the possibilities of adopting a standard still more advanced. We came to the conclusion at that stage that for the large amount of plant required it was going too far to advance quite so rapidly, and we adopted this 900 lb, 900° as a reasonable compromise and as a condition which would not involve any spectacular advance in boiler design, and I may say we had some 5 million kW of that plant on order before we had any of it in commission. In addition we planned a limited number of plants of larger capacities and more advanced steam conditions.

Some twenty-eight 60-megawatt generators have been put into commission since the war, and this size is rapidly superseding the 30-megawatt size which is now included in future programmes only to complete an early development or in exceptional circumstances. Of the 10 million kW of new plant now under construction or planned in programmes up to and including 1958, 6 million kW will employ steam at 900 lb and 900°, 2 million will be at higher steam conditions. A number of 100 000-kW sets to operate at 1 500 lb and at 1 050° are on order. It was felt at one time that these might become standard, but since then a number of 120-megawatt sets employing a reheat cycle with steam at 1 500 lb per square inch with an initial temperature of 1 000°, reheating to 1,000°, have been included in new stations in the 1957/58 programmes. We kept down at that time to 1 000°F with a view to keeping down the demands for the special alloy steels which were required for the high temperatures and which were very expensive and very difficult to get.

TABLE I

SIZES AND STEAM CONDITIONS OF GENERATOR UNITS AND OVERALL STATION THERMAL EFFICIENCIES (SENT OUT) WHEN OPERATING UNDER OPTIMUM CONDITIONS

Capacity	Steam pressure	Steam temperature	Thermal efficiency
kW	*lb/sq.in.*	*deg. F*	*Per cent*
30 000	600	850	28·3
60 000	900	900	30·3
100 000	1 500	1 050	32·8
120 000	1 500	1 000 with reheat to 1 000	34·7
200 000	2 350	1 100 with reheat to 1 050	37·6

Table I shows the various units 30 megawatts, 60, 100 and 120 with the steam pressures and steam temperatures and the optimum station efficiency sent out. I would emphasize that these are efficiencies which we would expect to get on test and for considerable periods, but it is better than we hope to get for the yearly performance. The actual yearly figures may in practice be less than those by up to probably 7½ per cent maximum. On the other hand certain of the stations will go, we hope, quite close to those calculated figures. On the 60-megawatt sets, for instance, we do have some stations which are running on a yearly basis at approximately 29 per cent thermal efficiency.

In 1920 the average thermal efficiency of all public supply generating stations was approximately 9 per cent. Over the last twelve months the average for all British Electricity Authority steam stations, new and old, has reached 23 per cent with the best figure nearly 31 per cent. We ourselves expect to reach 26 per cent average by 1960, and we hope that 30 per cent may well be in reach within the following ten years.

There are three outstanding features in the present development. First is increasing use of pulverized-fuel firing; the second is the adoption of the unit system for generators and boilers; and the third is the re-introduction of the reheat cycle. In 1939 only one-sixth of the total fuel consumption was in the form of pulverized fuel. In 1952 the proportion had risen to one-third and is expected to reach three-quarters by 1960. Consumption on stoker-fired boilers, which reached a maximum in 1951, has since fallen and will continue to fall in future. Pulverized-fuel firing enables a wider range and lower grade of fuel to be burnt efficiently in much larger boilers, and has the further advantage of being less subject in general to fouling in the boiler passes with consequent improvement in availability. That does not mean to say we are not going to get any trouble in boiler availability and fouling in the boiler passes. We have had one case in particular where using coal with a relatively high chlorine content we got rather bad fouling when the station first went into commission. Pulverized-fuel firing has led directly to the larger size of boiler and this has permitted employment of the unit system in which each generator is supplied by a single boiler instead of from a common steam range fed by two or more boilers per generator. By simplifying the steam pipework and eliminating spare boiler capacity with consequent reduction in the size of the boiler house buildings and in number of valves required, etc., the system offers appreciable capital savings and also makes for greater ease of operation. It has been adopted as standard practice for all future plants.

The reheat system originated in Great Britain at the North Tees station where it was introduced thirty-five years ago. By reheating the steam after expansion in the high-pressure section of the turbine higher efficiency was obtained without an increase in temperature which at that time was limited by the materials available to about 700°F at the turbine stop valve. With more than one boiler required for each generator, however, the reheat system was complicated to operate and as soon as suitable materials became available increases in thermal efficiency were more conveniently obtained by employing higher pressures and temperatures in the straight condensing cycle. In recent years, however, metallurgical problems have again put a check on temperature increases and with the adoption of the unit principle, the reheat cycle has found increasing favour. It has been widely used in the United States where on account of the better qualities of fuel which are available it has been possible to move faster with the design of large boilers than in this country.

An important development in the design of large turbo-generators is the introduction of hydrogen cooling. The use of hydrogen instead of air in the closed ventilation circuit has the advantages of reduced wind losses, greater thermal conductivity and improved heat transfer, so enabling a smaller machine to be used for a given output. For machines of 60-megawatts capacity and over hydrogen cooling has been adopted as standard.

FUTURE DEVELOPMENTS

Turning now to possible future developments, I would like to discuss first those dealing with improvement in thermal efficiency and then those concerned with utilizing sources of energy other than coal.

Steam conditions

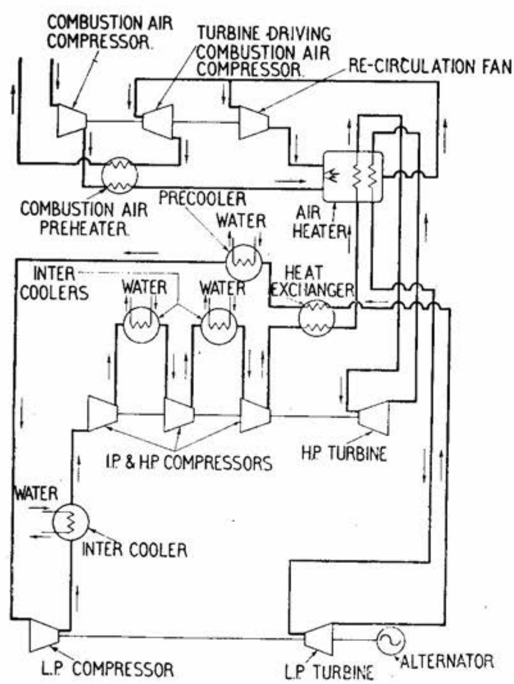
Future steam cycles may be broadly divided between those which are below the critical pressure of 3 200 lb per sq.in. and those which greatly exceed it, the latter being from 4 500 lb to possibly 6 500 lb per sq.in. Experience indicates that the safe limiting pressure for the drum type of boiler is about 2 700 lb, and the Authority is planning now for plant to work at this pressure to be commissioned in 1959. After allowing for pressure drops the turbine pressure will be about 2 350. With an initial temperature of about 1 100° and reheating at about 550 lb to 1 050° it is estimated that optimum sent-out efficiencies would be about 37·6 per cent when using highash-content British coals. The economic size is likely to be about 180 to 200 megawatts, and they could be built as either tandem-compound or cross-compound units both running at 3 000 r.p.m.

An experimental super-critical steam plant of 75-megawatts capacity is to be installed in Germany and another of 120-megawatts capacity in the United States, though the detailed designs are still in course of development. We think that these sizes are well below the economic sizes for such steam conditions. The American plant will be built for steam conditions of 4 500 lb and 1 150° with double reheat. An optimum sent-out efficiency of round about 40 per cent is expected by the designers, who further estimate that if they can put the pressure up higher with a temperature of 1 200 thəy might get up to 42½ per cent. It remains to be seen how near they go to those figures.

Gas turbines

Gas turbines offer prospects of higher thermal efficiency and the British Electricity Authority some years ago did order two 15 000-kW gas turbines of the open cycle. Unfortunately at the present time gas turbines can be operated only on relatively expensive oil and gas fuels and more recent estimates indicate that they are not likely to be economic for British conditions unless they can be developed for coal burning. The Minister of Fuel and Power in collaboration with other interested parties is carrying out a number of most interesting experiments into the use of pulverized coal and peas.

Figs. 5 and 6 show diagrammatically the arrangements for typical open- and closed-circuit gas turbines.



12,500-KW CLOSED-CYCLE SET FOR THE NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD

Fig. 5

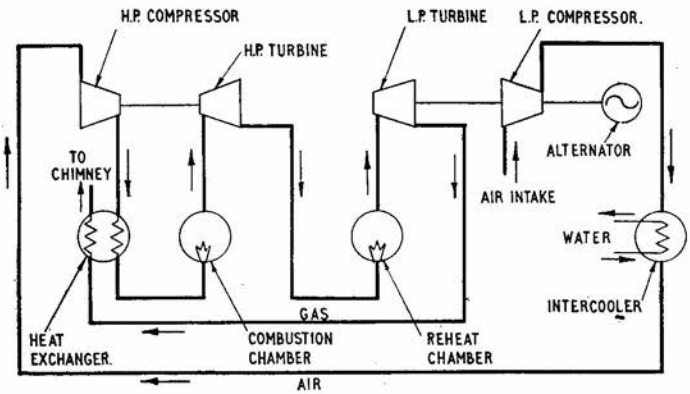


Fig. 6

Water power

It is clear, I think, that the bulk of England's electricity requirements must continue to be generated at steam power stations, but other sources of energy must be considered in a review such as this. First of all hydro resources in Britain are limited largely to Scotland and are being developed by the North of Scotland Hydro-Electric Board. There are some small resources in North Wales which may be developed at some future date, but at the present time when one of the difficulties is shortage of capital, it seems better to devote the available capital to getting more kilowatts in steam plant.

Wind power

The possibility of wind power is receiving experimental consideration in Britain. The Electrical Research Association have carried out reviews of the air velocities which might be expected all over the island and their general conclusion is that you might expect to get from 1 kW installed 4 000 kWhrs per annum. The North of Scotland Hydro Board have one on trial of 100 kW in the North of Scotland and we have one on trial of 100 kW. At the present time it is installed near St. Albans, but its final site, if we can get permission to put it there, is in mid-Wales. We decided not to follow the same lines as the North of Scotland Hydro Board which is the conventional wind generator with the generator at the top, and to adopt a design proposed by a French engineer, M. Andreaux, in which he uses hollow blades and as the propellor rotates air is drawn through the hollow blades, and the hub of the wheel is put in communication with the closed shaft which forms the tower and the wind generator can be situated at the bottom of the tower.

Tidal power

The possible utilization of tidal power also must be taken into account. The installation which offers most promise is the Severn Barrage. Unfortunately the Severn Barrage has been examined on two separate occasions and on both occasions it has been decided that it would not be economic at the coal prices ruling at the time. Nevertheless if the Severn Barrage had been constructed when it was first proposed, there is no doubt that it would have been very economical at the present time with coal at its present prices. One hopes there won't be such a spectacular increase in the price of coal as there has been during the last twenty years, but nevertheless there is a slow trend of increasing prices and it may well be that if the Severn Barrage were constructed during a slump period when labour was available and therefore capital costs relatively low it might reap the benefit of higher fuel costs in the future.

From all these sources in Britain our conclusion is that you cannot expect to make a contribution more than the equivalent of about 5 million tons of coal per year, and as the additional coal requirements over twenty years are likely to be five or six times that amount, it is obviously not the ultimate solution to the energy problem in Britain.

Nuclear energy

The source of energy which is most likely to supplement and in time to replace coal is, of course, nuclear energy and I should just like to say a few words about that.

The only natural nuclear fuel is the U^{235} isotope of uranium. This forms only 0·7 per cent of natural uranium, the balance consisting of the isotope U^{238}. It is possible to enrich the U^{235} content of natural uranium by an expensive diffusion process and this is done for some purposes. In the thermal reactor natural uranium or slightly enriched uranium is used with a moderator which reduces the energy of the released neutrons to thermal values. Considerable heat is generated and some of the U^{238} is converted to plutonium which is another nuclear fuel similar to U^{235}. In such a reactor, however, the amount of plutonium produced is less than the amount of U^{235} which is burned. The heat from thermal reactors can undoubtedly be used for electricity generation employing relatively conventional heat exchangers and turbine plant. An installation of this kind is being constructed by the Atomic Energy Commission in Cumberland and will probably produce about 40 to 45 megawatts. Until more experience is obtained with the construction and operation of such installations it is not possible to make reliable economic comparisons with coal-fired plant. It does not appear, however, that there will be any insuperable technical difficulties and it is not unlikely that the next three or four years will see a considerable extension of this type of installation.

In order to assess the possibilities of thermal reactors for electricity generation it is worth while considering the known world reserves of uranium in relation to the known reserves of coal and oil. If you take the thermal value of the latter, that is the known reserves of coal and oil, as unity, the availability of U^{235} is only of the order of 0·4, so that as long as we are limited to burning U^{235}, the increase in energy resources is not very great. I have already mentioned, however, that thermal reactors produce a certain amount of plutonium and this would increase to some extent the availability of energy arising from the U^{235}. It would, however, appear possible to make a large contribution to world reserves of energy only if a large proportion of the available U^{238} could be converted to plutonium. It is possible, by means of a different form of reactor employing uranium very much enriched in U^{235}, both to produce power and to produce plutonium from U^{238} at a greater rate than that at which the U^{235} is burnt. Such a reactor is described as a breeder reactor, which has been successfully developed in the United States, and an experimental reactor is being built in England. Assuming that by this means a very large proportion of U^{235} can be used, total energy reserves on the same approximate basis as already mentioned would be well over 40, that is 40 times the existing reserves of coal and oil.

A probable development of nuclear energy for electricity generation is therefore likely to be in two stages. In the first stage natural uranium or slightly enriched uranium would be used in thermal reactors which would burn U^{235} and produce a certain amount of plutonium. In the second stage, which cannot be commenced until breeder reactors are available, either uranium greatly enriched in U^{235} or plutonium would be employed. The way appears to be fairly clear for the first stage, but the second stage is dependent upon successful further development. It is understood that a further nuclear fuel uranium 233 could be produced from thorium in much the same way as plutonium is produced from 238, and this will afford a further very large increase in the world energy resources which could be used for electricity generation. It is as yet too early to forecast at all accurately the probable future of nuclear development. The present indications are, I understand, that with the thermal reactor the cost of electricity generated would probably be of the order of twice that from coal at present prices, but in a new development of that sort you don't know where you are until you have built experimental installations and have some more practical experience. I think there is not much reason to doubt that there will be several plants put into operation using thermal reactors within the next ten years. Within the next fifteen or twenty years the development of the breeder reactor may be well advanced.

DISCUSSION

H. H. JAGGER (Member): Mr Chairman, I would like to thank Sir John for his very interesting talk. It has been most interesting to me personally and I think we have all learnt a great deal from what he has told us this evening. I was a little disappointed that Sir John didn't just touch on the spreader stoker. We, the Cape Western Undertaking of the Electricity Supply Commission, have embarked on the installation of spreader stokers and in two years of operation at the Hex River Power Station our experiences have been quite satisfactory. We have heard that the spreader-stoker installations in Great Britain at Kearsley and Staythorpe have not been, I understand, as successful as we have experienced at Hex. I should be glad if Sir John could just digress a little and give us some information on the spreader-stoker installations at Kearsley and Staythorpe.

SIR JOHN HACKING: At the time when we decided to put those two installations in at Kearsley and Staythorpe we were very hopeful that the spreader stoker would enable us to go beyond the capacity which is practicable with normal chain-grate stokers. We thought we might manage to get stokers up to about 30 megawatts, 300 000 lb per hour or more, and we might make them a unit with 30-megawatt sets. The experience has not been entirely unsatisfactory. The experience at Kearsley, for example, has been quite satisfactory. The experience at Staythorpe has not been so satisfactory, and I think it has been due to a multitude of causes and perhaps the design of the heating surfaces may be one of the contributory factors. We did have some trouble with those particular stokers. The only reason why we have not gone further with them is because of our desire, in order to reduce the capital costs of stations, to go to unit boiler installations, and as I have already indicated to you the bulk of our sets which we are putting in now are 60 megawatts and above, and I don't think the spreader stokers are a practical proposition for a 540 000-lb per hour boiler. I know that the installation at Hex River is behaving satisfactorily from what I saw of it yesterday.

DR H. D. EINHORN (Member): Could Sir John tell us anything about recent developments in load control, by which I don't mean power cuts!

SIR JOHN HACKING: Yes, the question of load control has been considered quite a bit in England. There has been considerable pressure from the Government and other sources for quite an extensive programme of installation of load-controlling devices. Their ideas were not so much to use them for water heaters but to use them as a means of limiting the peak demand, and we did investigate that matter in quite considerable detail with the Government people who were sponsoring it and we reached the conclusion that it was not an economic proposition. We have a number of installations, of course, using these load-limiting devices, ripple-control devices, on water heaters, and that on account of the storage seemed to us the only really satisfactory method of using them. Our statistics, however, in connection with water heaters indicated that at the time of the morning peak there was probably not more than about one-third of the water heaters in use at any one time, and at the evening peak which was our greater concern the percentage we reckoned was still smaller. Conditions may be different in this country.

J. McHUTCHON: Are British manufacturers developing direct cooling in generator design?

SIR JOHN HACKING: The British manufacturers are doing that and in fact I might have said that on the 180- or 200-megawatt sets that we are investigating at the present time we should certainly require direct cooling by means of hollow conductors in order to get rid of the heat and keep down the size. We have no such installations, but certainly British manufacturers are investigating it and it is not unlikely that we shall have installations of that sort. We regard it as a very favourable development and one that we shall probably be using.

B. W. KUTTEL (Graduate): Have British authorities considered the use of gas-turbine sets, roughly 15 MVA, during peak-load conditions at steam-turbine power stations on account of quick starting.

SIR JOHN HACKING: It becomes a question of economics. Britain is a coal-burning country. The price of oil for the equivalent calorific value is materially higher there than coal and therefore the running costs of a gas turbine, even if you get the improved efficiency which you can get by other means, would be materially higher. That, of course, might be offset by reduced capital costs, and when we ordered these two 15-megawatt sets at the prices which were quoted to us our assessment of the position was that it would be economic for annual load factors not exceeding 12 per cent. We have a number of stations which run at a load factor as low as that. As the manufacturers developed the designs of these sets I believe the costs came out much higher than they anticipated. The question as to whether or not they will be used in the future depends on many things, particularly on the possible development for coal burning.

J. M. GEORGALA (Associate): With reference to the submarine cable linking the grid system with Northern France, what developments were likely with regard to pooling of facilities.

SIR JOHN HACKING: Together with the French Supply Engineers we carried out a very detailed investigation and came to the conclusion that on account of the different incidence of peak demands in the two countries there might be possible economies in plant installation between the two countries of up to about 300 000 kW. The installation we contemplate might go in—I say *might* because we have not yet decided to do it—was being planned for 100 000 kW at 132 kV. We carried out trials on laying of cables along the South coast of England. We laid about a mile and a third of cable just to get experience with it and see how it behaved, and see whether we would have any troubles in laying—not to put it into service. The French engineers are carrying out further similar trials this autumn on their side of the Channel in which we are co-operating, as they co-operated with us, and a decision will not be taken to proceed with the interconnection until after those trials are complete.

E. T. CLIFFORD-JONES: From Fig. 1 the domestic load appeared to be a very small percentage of the total potential load, and much the same sort of thing seemed to apply to the traction load. With a view to conservation of coal, what consideration is given to these two forms of load?

SIR JOHN HACKING: The percentage of our total supplies which are used for domestic purposes is roughly one-third, industry about one-half and commercial is of the order of one-eighth or a little more. The relative peak demands of the two are very, very difficult to assess with any accuracy as it depends entirely on statistical analysis. It is very important that the domestic load should be developed because so much of it is an off-peak load and we look to it to improve load factor.

J. C. BAILLIE (Associate Member): There seems to be a general reluctance to use pulverized fuel both in England and this country. What factors were responsible for the changed attitude overseas?

SIR JOHN HACKING: Improved equipment and design of boilers have led to a better realization of the problems associated with the burning of pulverized fuel in large boilers and our experience over the last ten years doesn't lead to any adverse view of pulverized fuel. I would also remind you that there are tremendous installations of pulverized fuel-fired boilers in power stations in America. We have not come across any serious difficulties with the more recent installations of pulverized fuel. I would say that we consider it is essential to associate with pulverized-fuel installations an adequate system of grit extraction. We also believe firmly in disposing of the grit at a high level away from any disturbance in the air stream caused by the presence of the building itself, and with that in mind we always put the stacks up to at least two and a half times the maximum height of the building which is usually the boiler house.

J. MCHUTCHON: Has any use had been found for the ash from pulverized fuel-fired boilers?

SIR JOHN HACKING: We have carried out quite a lot of investigation into possible uses of pulverized-fuel ash and we are continuing to do so. The biggest present commercial use is in mass-concrete construction. Pulverized-fuel ash enables you to reduce the amount of cement in mass-concrete work. It reduces the temperature as the concrete sets and reduces the stresses. It has been used quite extensively in one or two big dams in the United States and I do know of one station in the United States which uses it in its own mass-concrete work for the foundations of one of its own stations. It is also used to some extent both in the States and in Britain in association with fillers for road surfacing. Research that we have had carried out shows that it can be used very satisfactorily and probably economically for the manufacture of light-weight concrete blocks. We are carrying out research into the possibility of brick making. We think that satisfactory bricks can be made with it. The bulk of our pulverized-fuel ash is, however, used in filling up marshland and places of that sort, filling up old gravel pits, levelling them off, etc. We have carried out tests on the growing of crops in thin layers of soil on top of the pulverized-fuel ash with fairly satisfactory results. We have research going on in two universities, one including the possibilities of binding it with a mixture of soil and refuse from sewage plants. We are carrying out a lot of research, but I would not like to say that we have got what we regard as any really satisfactory solution. The disposal of those large quantities of pulverized-fuel ash is a big problem.

C. W. EVERETT: Why has standardization in Great Britain been made so conservatively on 60-MW turbo-generator sets in the light of the trend of design in America?

SIR JOHN HACKING: I think there is need for a certain amount of conservatism because after all reliability of supply is a thing which should be dear to the hearts of power-supply engineers. At the end of the war we were faced with the problem that we knew we had to have a very big expansion in the generation resources. It was in our view vital that we should not only make an advance in the steaming conditions and improvement in efficiency, but also that we should do so without risk to reliability. That is why we adopted 900 lb 900°F as one of our standards but we never intended to use standard plant for 100 per cent of our requirements. Our broad assessment was that we should use standard plant for approximately 80 per cent of our requirements and that we should experiment with the remaining 20 per cent with a view to establishing standards for the future. That is why we have installed some 60-megawatt sets at 1 050°, we are installing 100-megawatts sets at 1 050°, whilst the 120-megawatt sets will operate at slightly lower temperatures with reheat. Our proposals for 180/200-MW sets are pretty well equal to anything the Americans are doing except for the super-pressure plants which they are trying out.

S. S. WOLFE (Associate Member): What is the voltage of the large generators being made?

SIR JOHN HACKING: Most of our stations now are switched at voltages not less than 33 kV. Most of them at 66 kV and an increasing proportion of them at 132 kV. On account of those two higher voltages there is less and less justification for generation at 33 kV. We have put in some 33-kV generators where the switching has been at 33 kV, but they are a reducing number.

DR H. D. EINHORN (Member): On what voltage would the d.c. cable be operated?

SIR JOHN HACKING: The suggested 132-kV a.c. cables across the channel would be suitable for operation at 200 kV direct current.

THE CHAIRMAN—C. G. DOWNIE (Member): Sir John, I am surprised that nobody has asked you a question on atomic energy yet. There is nothing that has so captured the public imagination in Cape Town, now that they have been told that the City has decided to build a new power station, as atomic energy. People know that the Railways have got to transport nearly 700 000 tons of coal to Cape Town's power stations during this year and they have heard that the same amount of electricity can be obtained from a few tons of uranium so that if we could employ uranium it would be a matter of using transport facilities for a few tons, whereas the railways have to struggle all the way, a matter of 1 000 miles, with hundreds of thousands of tons of coal. You have told us that from an economic aspect the cost of a kilowatthour of electricity produced from atomic energy at its present stage of development is about double the cost of production from coal.

(Sir John: For our conditions. It might well be more for your conditions.)

C. G. Downie: Some influential people also in Cape Town are going around telling others that we must wait a bit. We must not build another power station. We should bide our time and 'cash in' on atomic energy. I reckon that if it is going to take the B.E.A. ten years before it can exploit atomic energy on the same scale as that for coal-fired power stations, it may be at least twenty years before we can start using atomic energy here. We know about atomic reactors; that reactors can be built from which you can get the heat to produce steam to drive turbo-generators, but what we have not been told is what are the snags involved in the operation of these reactors. One hears about atomic ash and fission products. One is told how dangerous fission products are. Aren't the difficulties inherent in the operation of these reactors going to rather stifle the application of atomic energy to the production of power? We have not heard much about that side of the business of using atomic energy and I am wondering whether enough is known about that aspect to enable you to tell us whether there are going to be any insuperable difficulties from the operational side. One sees pictures of operators dressed up in extraordinary overalls and wearing fancy boots and helmets and all the rest of it. Does it mean that a fireman in an atomic energy power station will have to walk around dressed up like those fellows you see in the Brick Bradford cartoons! One can understand that after you have got the energy from the atomic boiler and converted it to steam you are just where you are to-day in the ordinary turbine house, but I am just wondering whether in the atomic boiler house there is not going to be serious trouble from the operators' aspect and also what the difficulties are in disposing of atomic 'ash.'

Sir John Hacking: The atomic power station may be divided into two parts, one includes the heat exchanger and the power plant which is more or less normal, and the other includes the reactor. With the reactor you would have to take all the precautions that they take with the reactors now. There is, of course, the further problem of disposal of the fission products which are undoubtedly dangerous. The method of disposal may simply be to store them up in a safe place underground until they lose their radioactivity. Some of them, I believe, have relatively short half lives and possibly after four or five years you could handle them with reasonable safety. I am sure these are matters which are receiving adequate consideration by the atomic energy people and we can only look to them to provide the necessary solutions.

I consider that there is a considerable period of research and development necessary before anybody really knows what is going to be required in these atomic power stations, what the economies are going to be, and you won't get that experience except by carrying out trials. There is probably more incentive in Britain to carry out those trials than in most countries in the world on account of the prospective coal situation there. I would have thought that it would not be desirable for a country like South Africa to undertake that sort of development. It would be far better to wait for someone else to do it and give you the benefit of their experience. Until more experience is available, Britain is not going to stop building steam power stations to meet its essential requirements. I think that would be a very foolish policy.

VOTE OF THANKS

Mr Joseph White: Mr Chairman, Sir John, gentlemen, I greatly appreciate the honour of being asked to propose this vote of thanks to our guest speaker this evening. You will realize that I am speaking on behalf of the Cape Town members of the Institution of Electrical Engineers and also on behalf of the Cape Western Local Centre members of the South African Institute of Electrical Engineers. We are greatly indebted to Sir John for sacrificing his valuable time to come and address us to-night. It is really very good of him and I would like to record our thanks to him for doing that. As you all know, Sir John was the President of the Institution in London in 1952, and the achievements and the success of his year in office are still fresh in our minds. I would ask Sir John if he would be so kind as to convey our greetings to the President and Council in London and to assure them of a very hearty welcome should any of them at any time come to South Africa and Cape Town in particular. By a very curious coincidence just as I heard that Sir John was likely to be with us here I was reading an appreciative article—that is appreciative of the British Electricity Authority—in the *Illustrated London News*. It was written by a well-known columnist, Mr Arthur Bryant, and he made one or two points rather striking. He said first of all that electric fires have been turned on in the British Electricity House. Now that seems a very ordinary and probably ambiguous remark to make, but the reason for it is rather fascinating. It seems that over the past several years when there have been power cuts in Britain the Chairman and the senior executives of the British Electricity Authority sat at their desks with their overcoats on. They imposed upon themselves this idea that as long as there were power cuts in Britain they would not switch on their electric fires, but in February this year when there was a very cold spell the electric fires were switched on because there had been no power cuts and the Chairman and his right-hand men didn't have to wear their overcoats in their offices. The second point that Mr Bryant made was that he praised the efficiency and the promptness and the courtesy of the engineers of the British Electricity Authority at all levels and he cited an instance when a breakdown gang had worked all through the night in a very heavy storm to restore power to a somewhat remote farm so that some twenty or thirty cows could be milked at daybreak. Now this experience of breakdown gangs and service must ring a bell among so many South African engineers. We have all had that to do, but it was to me very heartening to think that a first-grade columnist should deliberately write an appreciation of the work of the electrical engineers and of the mechanical engineers of the British Electricity Authority and I solemnly and sincerely convey this idea to our journalistic friends in South Africa. Mr Bryant deduced from these two widely different incidents that the British Electricity Authority was led from the top and from the front, and it was not controlled by anonymous executives sitting in remote seclusion somewhere in the background. The idea of service is not new to us here. We endeavour to do our best too, and my mind goes back to the early days of the V.F.P. when if power was off from any individual consumer for more than fifteen minutes, the V.F.P. had to pay out on penalty. Those days have gone, of course, but I like to think that that idea of those days—that service—is the one that imbues us to-day, and I also like to think that this idea of service is due in a very large extent to the magnificent example set by that prince of engineers and administrators, the late Dr Bernard Price, followed by that eminent founder of the Electricity Supply Commission, Dr Hendrik van der Bijl. We honour the memory of these two men, not only for their own achievements, but for the personal interest that they took in our Institute and in the progress of our Institute. With these few words it gives me great pleasure to propose a vote of thanks to you, Sir John, for your very inspiring address.

MR LARKIN (Vice-Chairman), in seconding the vote of thanks to Sir John Hacking, remarked that it is seldom that a South African institution is honoured by being addressed by so distinguished a visitor, and moreover it was the first occasion that the Cape Western Local Centre had been so honoured.

The graph illustrating the rise in the rate of manufacture of generating equipment overseas to meet the increasing demand, resembled a parabolic curve, and indicated the tremendous increase in production in the face of numerous obstacles—many of which did not exist in South Africa and clearly showed the industry's progress against great handicaps.

The serious effect of the war years had been most apparent.

Mr Larkin said that the address had been most inspiring and interesting and that it gave him great pleasure to second the vote of thanks.