DISCUSSION ON "TARIFFS."

BEFORE THE INSTITUTION, 28 APRIL, 1921.

The discussion was opened with introductory papers by **Mr. J. R. Blaikie,** Member, entitled "Electric Supply: Present Conditions and the Hopkinson Principles" (see page 701), and by **Mr. J. W. Beauchamp,** Member, entitled "Multi-part Tariffs for Domestic Electricity Supply" (see page 714).

The President (Mr. Ll. B. Atkinson): I think the method Mr. Blaikie has adopted, of taking two or three different years where the class of load has varied and of finding certain factors by an equation, is at least quite novel. That method of ascertaining some of the constants is one of the points that will justify a very full consideration of the proposition which he has put forward. I am not quite sure in my own mind that the division of consumers into 6-day and 7-day groups, beyond being a broad method, is at all correct, because it is found to be not so much a question of the group to which they belong as whether they are users during particular, well-defined hours of the day. Mr. Beauchamp's paper gives some useful particulars of how to achieve what we are all struggling to do, i.e. to get electricity supply installed in the new dwellings which are being erected in such large numbers throughout the country, and where only a moderate expenditure on lighting and heating is entailed. The Council desire to give this question of tariffs the very fullest consideration, both from the technical point of view and also from that of what may be necessary in regard to alteration of the legislation by which we are at present guided. It is necessary first of all for engineers to arrive at the proper method of charging, and then, if it transpires that legislation is necessary, we shall go forward with much greater force if we have thoroughly established in our minds that the present system is inapplicable or unfair under existing conditions.

Mr. Arthur Wright: I think the Hopkinson principles should be supplemented as follows: (*a*) Acknowledgment that it is commercially impossible to measure the demand on the investment by the intermittently-used, small and ever-increasing electrical appliances in domestic houses, whose diversity factor entitles them to a good load-factor rate. (*b*) The advisability of granting rebates in proportion to the total consumption of electricity. (*c*) The necessity of making an adequate service charge. (*d*) The wisdom of looking to the running charge as the main source of profit. And (*e*) the necessity of a power-factor clause based on a kilovolt-ampere demand and not on average power factor. With these additions I still believe that the Hopkinson principles enable us to make the best and most equitable tariffs and analysis of costs of supplying electricity. There are now in use two distinct types of tariffs: those based on what the market can bear and those based on a reasonable profit on the cost of supplying each individual consumer. While the first has the advantage of following ordinary trading practice and is easy of application, I think that the second has greater chances of extending the use of electricity in profitable directions and of meeting with the support of Public Service Commissions because of its greater equity. A compromise between the two should also be considered, as it can be justified on many grounds; namely, a tariff based upon the maximum amount the market will bear above the increment Hopkinson cost of the additional supply. The test of a correct tariff is the annual rate of increase of a profitable load, and only the Hopkinson analysis can enable this to be done. The usual analysis of average cost and company's profit-and-loss accounts does not enable us to determine, for instance, when interconnection is advisable from a generating point of view. In my opinion, standardization of accounts on Hopkinson principles should now be attempted, so as to provide for the time, which is bound to come in the near future, when finance will not permit of the further installation of generating plant in a city when a supply at lower cost can be obtained from outside. It should be remembered that there is now no great difficulty in ascertaining the cost of supplying electricity to the end of feeders, or to substation switchboards, and, as the revenue of a district is equally ascertainable, a correct profit-and-loss account of a district can be made out. This also applies to large consumers and bulk supply. Therefore it only remains to allocate among the various smaller customers the distribution demand and service cost, and of these the service cost is easily ascertained. The remainder must, for the present, be arrived at by a cut-and-try method, tempered by expediency. The office and window lighting of shops will not, in my opinion, permit of any profit, and must be looked upon as a tax for the concession or a gift to a city for reasons of policy, because the sufficiently high price would not generally be permitted in this country. Experience abroad has convinced me that rapid electrical development depends as much on efficient salesmanship as on simplification or lowness of tariffs; in other words, the selling department should be looked upon as the most important one in the business and the best men should be encouraged by attractive salaries. In case any members should think that complication in charges for electricity tends to retard electrical development, I invite them to study the elaborate rates adopted by the very successful (electrically) cities of New York, Chicago, Los Angeles and Boston. These are fully given in the National Electric Light Association Year-Book. The reason that complicated tariffs are successful is the general confidence that people seem to have in the Public Service Commissions. They now realize that rates are a very technical matter which they cannot hope to understand. We cannot make rates intelligible to the general public; the theory is far too complicated. Mr. Blaikie appears to think that the present-day fixed charges bear a smaller proportion to the total cost of electricity supply than they did in pre-war days. This may be so on his pre-war investment

but tariff discussions should be based on future costs and ratios, and I think he will find the ratio will be as great if not greater in the future, especially if he continues to separate his coal into stand-by and running costs. I think the cost of coal and rough labour will, in the future, diminish more rapidly than the cost of money, equipment, taxation, skilled labour and management. We have lately been so occupied with the coal shortage and labour troubles that we are apt to overlook the fact that there is at present, and will be for a long time to come, an equally serious shortage of something that concerns us almost as much, namely, capital, of which there is very little available for electrical purposes and which has also struck for a much bigger rate of interest than it obtained seven years ago, for the very good reason that it can obtain it. I am convinced that electrical development in this country will not be able to get the requisite capital for extensive progress until it is recognized by the powers that be that there is now a very limited amount of money available for all industrial enterprises, and that the past returns on electrical investments, in view of the rapid obsolescence of plant, etc., have not been encouraging. Until electrical authorities are allowed a return on their ordinary capital amounting approximately to double the average bank return during the year in question, and obtain a permanent tenure with the ordinary business practice purchase clause, it will be difficult to obtain capital. While the last seven abnormal years form no criterion as to future costs of supply, or the correctness of existing tariffs, they have been of substantial use to the electrical industry, (i) in greatly increasing the appreciation of the necessity of a general electric supply; (ii) in the creation in this country of an independent Government department of experts to help in electrical matters; (iii) in obtaining authority for raising the maximum charges; (iv) in helping to realize the necessity for a more efficient use of capital, skilled labour and fuel; and (v) the lesson has been learnt that all great industries dealing with two or more towns, to be run efficiently must be managed by well-paid men and financed by private capital. Experience has convinced me that the radius of economical electricity supply to-day exceeds the radius of efficient municipal control, and that a free trading monopoly with long tenure, under the control of expert Public Service Commissions, is vital to successful electrical development. I do not at present understand Mr. Blaikie's grouping of consumers into 7-day and 6-day groups, and I hope he will enlarge on that point in his reply. The Hopkinson principle supplies all the division that is necessary for determining the rates. I entirely agree with most of Mr. Beauchamp's conclusions. There is one subject which I have carefully studied, namely, electrical cooking. On the other side of the Atlantic it has developed to enormous proportions, but it has been found there that the old standard of regulation of pressure has to be departed from very largely if sufficiently cheap electricity for cooking is to be supplied. Unless cookers can have some automatic thermostatic control to allow for varying pressures so that the consumer does not complain that the cooking takes three times as long as it should, due to low pressure, or unless the cookers have multiple switches so as to provide for the lower pressure, it will always be extremely expensive to supply electricity for cooking, because in winter the latter synchronizes with the peak. There is no reason to-day, in my opinion, why the old pressure regulations, which are based on carbon-lamp efficiencies, should be maintained. The metal-filament lamp is almost self-regulating on pressure, and it is found that consumers will stand a very much bigger variation of pressure than they could when carbon-filament lamps were used. The cooking business is so huge and so promising that it is worth while for manufacturers and everybody else, first to get the regulations in regard to pressure modified, and secondly, to get the apparatus adjusted so as to work efficiently under slightly different pressures.

Mr. H. W. Couzens: I propose to devote my remarks to Mr. Beauchamp's paper, which I consider to be of paramount importance. Now that the arrears of post-war consumers have been practically cleared off by the supply companies, the next important field is that of cooking. Hitherto, cooking apparatus has been developed by the manufacturers and traders, with the central station engineer as a mildly interested spectator. That is all wrong, and I think the central station engineer has to take the primary place. One of the most important features, apart from the hire of apparatus and propaganda by educated instructors, is the development of a tariff which will appeal to the ordinary consumer. I have recently taken a small flat in London where the tariff for electricity supply is 8d. per unit for lighting, 3d. per unit for heating, 2½d. per unit for power, and 1½d. per unit for cooking. This was too complicated, and I therefore went to the supply company, and we made an estimate of my lighting requirements. We added £1 to that, and I now pay £5 per year plus 1½d. per unit. I use electricity for all purposes except domestic hot water, and the amount I have to pay is about £15 a year, so that the supply company receive nearly four times as much as they would otherwise have done, and I am thoroughly satisfied with the bill. I think it would be very difficult to make a rigid fixed charge at the moment, because the circumstances in regard to electric cooking, particularly as to the maximum demand, are not thoroughly known. Take, for instance, the Brompton and Kensington Company. They tell me they have about 500 cookers on their circuit, and they have developed the load within the last 12 months so that there are now about 2 000 kW installed for cooking purposes. Their maximum load in respect of that is rather difficult to ascertain, but appears to be not much more than 250 kW. Therefore it does not seem to me to be necessary to make the fixed charge too high. On the other hand, the fixed charge ought to be simple, so as to be understood by the consumer. I recently received a "Schedule of Electricity Charges" from an indignant consumer who is supplied by a Borough Council in Greater London. The rates for power, heating and cooking are on a sliding scale, and are very high. There is an alternative "telephone system" at a charge payable quarterly of £30 per kW per

annum of maximum demand, plus 2d. per unit. That is enough to frighten anybody. With regard to the question of mains, I do not think the distribution will be quite such a difficult problem as some people imagine, particularly where the supply is alternating current. Where it is direct current I think it will be necessary to change over to alternating current.

Mr. P. D. Tuckett: I propose to confine my remarks to Mr. Beauchamp's paper, which seems to me to afford a way out of the difficulty in which a large number of the smaller undertakings in this country are now involved. At the present time, under the maximum lighting rates which they are allowed to charge, many of their lighting consumers are being supplied at a loss, which other consumers are necessarily called upon to make good; in fact, in certain cases the present tendency is for the maximum price to become the minimum price. It is entirely uncommercial, but is inevitable with the artificial and arbitrary price restrictions to which we are subject Under a multi-part tariff, with a fixed quarterly charge adequately covering the standing costs, this difficulty would be avoided, whilst the comparatively low unit charge would encourage consumers to make the fullest possible use of the supply. I am in substantial agreement with Mr. Beauchamp's arguments in support of a multi-part tariff, but there are one or two points to which I should like to refer. First, I think it is hopeless to try to secure a scientifically correct or uniform tariff. The conditions vary in every town, and we all know the practical objections to attempting to apply a scientifically correct tariff. What we want is either much higher maximum rates as an alternative to our permissive multi-part tariffs, or the right to enforce these tariffs in place of the present flat rates. I am sorry to say I do not share Mr. Wright's confidence that the controlling authorities in this country can be relied on to sanction compulsory multi-part tariffs to yield an adequate return under the varying conditions which exist, and I should therefore prefer a high maximum rate, leaving each undertaking free to secure the adoption of an alternative multi-part tariff on its merits. At present, owing to the inadequacy of the maximum rates, there is great difficulty in applying a permissive multi-part tariff where it is most needed. There may, for example, be a number of identical houses with bills ranging from £5 to £15, with an average of £10, owing to the very different use which the various consumers make of their installations. Under these conditions, with an insufficiently high alternative flat rate, a permissive multi-part tariff based on the £10 average will be readily adopted by the £15 consumer but will not be entertained by the £5 consumer, and consequently, so far at any rate as existing consumers are concerned, the initial tendency is for the undertaking to lose by its adoption. In connection with the determination of the proper fixed charge under a multi-part tariff there is a very important consideration, referred to by Mr. Beauchamp, which I should like to emphasize. He points out that if the encouragement of the domestic load is to be capable of indefinite development the tariff must be based on the post-war cost of capital and plant so as to ensure a steadily-increasing and productive return. Otherwise its very success will bring financial failure when the expansion of the business calls for new plant and mains at 3 or 4 times their pre-war cost, for that is what I am afraid they are likely to cost for some years to come, when the higher cost of capital is added to their higher cost. There is one point in connection with the development of the domestic load which I am inclined to question, viz. the encouragement of a low-priced accessory heating load; I am not speaking of cooking. Are we satisfied that the ordinary radiator load is so much better than the lighting load as to justify a very much lower charge being made for it? It is mainly a winter load and is liable to overlap the peak of the lighting load, without, I think, having any better load factor or a much better diversity factor. Under these circumstances I find it difficult to believe that it is really a paying load at rates greatly below the lighting rates.

Mr. F. W. Purse: The subject of tariffs is the be-all and end-all of the existence of those connected with the electricity supply industry, because the spending of time and money in getting the last refinement is of no use if we cannot sell our electricity at a profit. Mr. Beauchamp read a paper of a similar character before the Incorporated Municipal Electrical Association last summer, and I differed from his conclusions to some extent. He says that we must look at this question from the point of view of load rather than from that of individual consumers. A consumer will see how much the one next door is paying and will be always complaining. We know that in the case of companies the latter tell their consumers they must "either take it or leave it," but with municipal authorities the consumer can come to the Council and argue that the engineer is mistaken and that the tariff is wrong. That is the sort of trouble with which we have to contend. I do not like Mr. Beauchamp's suggestion of starting with £5 for so much, then adding another pound and then another pound. We are asked to make the tariffs simple, but it is not simple to go to the consumer and say: "We shall charge you £5 and 1½d. a unit for lighting and allow you to use a few accessories. Then if you install a range it will cost £1 extra per kilowatt, and so on." That means an equivalent of four or five tariffs, and it is not simple. The consumer wants to know what he will have to pay in the end. I agree with the other speakers that we have sold electricity at too cheap a rate. Consumers do not mind paying a little more if they get satisfaction, but we require the apparatus as well as the tariff to do so. I think it is of all-important interest to manufacturers to produce goods worth handing over to our consumers. I mentioned at Ilkley last year that we had in the North the old 0·5d. tariff. In effect that worked out that the lighting was equivalent to the flat lighting rate and everything else was at the ½d. rate. Consumers would not have minded if it was 1d., provided they could have obtained well-made apparatus. I want to impress upon manufacturers that they must produce apparatus which we can put into consumers' premises and forget about, and not have to pay for maintenance twice the amount that we receive for hire. There is one point which is continually em-

phasized in connection with the multi-part tariff and which I have often protested against, namely, to have one meter and one system of wiring throughout the house. The lighting circuit must be kept absolutely separate from the heating and power circuits throughout the house. A single meter may be permitted, although I do not altogether agree with that method, because if all the consumption is registered on one meter it must be big enough to carry 25 amperes. It may be said that a loss of a few units can be afforded, but if a few units at 1½d. are lost all round, what will be the effect on the electricity undertaking? I do not think it will pay. Then Mr. Beauchamp suggests that we ought to go in for generous mains extensions, but, in view of what they cost at present, we can hardly do that. We have always been deterred by the cost. We have never received enough money for our current to encourage us to go on laying mains and, as Mr. Wright says, the position will be worse in the future. I think Mr. Beauchamp is a little unhappy in his suggestions with regard to the tariff. He says: "Suggested skeleton domestic tariff." It will be noticed on page 716 that he gives £5 plus 1½d. per kWh, and then he adds some extras and makes a total of £25. He gives us, again, another example of 300 kWh for lighting and he makes the total £28 10s. He goes back to 8d. for lighting. It is not very important, but it would have been rather better for comparison if he had kept the details exactly the same. Generally, with regard to a multi-part tariff I entirely agree with him if the two-rate tariff can be imposed as an alternative to a fixed charge, but I entirely disagree with estimating and similar work going on. We must endeavour as far as possible to measure it, otherwise there will be complete dissatisfaction, which is most disastrous to satisfactory management. I think both the papers show that the cost of lighting justifies a charge of at least 8d. and in some districts 1s. a unit. Electric lighting is cheap at that price, and people will pay it. Mr. Blaikie's paper is an excellent exposition of the reasons for differentiating between lighting and power charges, and explains them in a way which has never been employed before. I am, like Mr. Wright and other speakers, not altogether in agreement with Mr. Blaikie's method of grouping. He says that lighting is the 7-day group and power is the 6-day group. The "Sunday load" term has crept in because of the 47-hour week in the generating station, but I do not think that has made all the difference. We have to recognize that the principal load is the lighting load; it is the peak load, and any load, whether it be power or lighting, 6-day or 7-day, that comes on the peak must bear a higher charge than one which does not come on the peak at all. Mr. Blaikie wants to omit the 6-day lighting, but I consider this is equally a peak load and should also have a higher charge. Mr. Blaikie says on page 702 that the "capital charges are much less per kilowatt in the 6-day group, for many reasons." I do not agree that the capital charges are much less for shop lighting which, as Mr. Wright has pointed out, is one of the most disastrous loads possible. It is the cause of a great deal of our trouble. This statement is made on page 711: "Since we have seen that one group consumes nearly three times as much coal as the other, a coal clause based on the average consumption means that one group is being subsidized by the other. Obviously, each group should have its own coal clause." That answers the point that has been made several times recently with regard to increased charges. Those of us who had a coal clause have put up our costs by so much, perhaps ½d. or ¾d. per unit, because of the increased cost of coal. Several wiseacres have said: "Yes, you have raised the power load rate by ½d. or ¾d., but why, just because the cost of coal has gone up, have you raised your lighting rate 2d.?"; and it has been difficult to convince them. Mr. Blaikie has shown very well why it is necessary to charge a larger proportion throughout. I disagree with his statement on page 712, where in referring to the 7-day group he includes power. He puts his 7-day group in the analysis at £17 per kilowatt. I assume, therefore, that he would include a power load which was in the 7-day group at £17 per kilowatt, whereas if it were a 6-day load for power he would put it at £4 per kilowatt. A rate of £17 per kilowatt at 100 per cent load factor is equivalent to 0·466d. per unit. That would be his 7-day group. If exactly the same load is obtained only on 6 days a week, omitting the Sunday—that is, Mr. Blaikie's 6-day load—it is obtained at £4 per kilowatt. That 6-day load gives approximately an 85 per cent load factor if it runs for 6 days a week and every hour in the day. £4 a kilowatt on an 85 per cent load factor is equal to 0·13d. per unit; in other words, Mr. Blaikie suggests that because he runs all day on Sunday and increases his load factor from 85 to 100 per cent his fixed charge for every unit has to be increased from 0·13d. to 0·466d. I cannot agree with his contentions in that respect. Then he includes traction and public lighting as a 7-day group, but I certainly cannot agree with the sub-division that he puts in; nevertheless, I think his analysis very useful and one that will be very helpful to us in framing tariffs. Consumers at present have the option of choosing whatever they like, and unless, as Mr. Tuckett suggested, they can be compelled to adopt the multi-part tariff, and unless the maximum charge is sufficiently high, the multi-part tariff will not be as successful as we hope. Before it can be a success we must have reliable apparatus. I agree with what Mr. Tuckett said on the question of heating. I have maintained, and still maintain, that there is no proof that a certain amount of heating load is worth more to the undertaking than the same amount of power load. If that is so, why should less be charged for heating than for power?

Mr. E. W. Cowan: Both papers refer to the two factors which when taken together determine price, namely, the cost of service and the value of service. For many years consideration was given only to the influence of the former. The present papers give evidence that that attitude no longer prevails. The electric supply industry is, I think, gradually taking its place with other industries in endeavouring to adapt prices to market conditions, as only in this way can any industry be of the greatest advantage to the community. To consider cost of supply only is not incorrect, but it is inadequate. Unfortunately, there

has been in the past a tendency to regard consideration of the influence of value of service as involving neglect of the proper influence of the cost of service. That is a mistake that Dr. Hopkinson never made, and I am glad to note that Mr. Blaikie's paper supports efforts I have made in the past to dissociate Dr. Hopkinson's name from responsibility for rigidly basing tariffs upon cost of service. Both papers strike a note of freedom from that restricting and, I submit, unscientific method of arriving at tariffs. After all, the cost of service to any individual consumer is indeterminate. The aggregate cost of service is determinable for any selected period, but the cost of service to any one consumer is not. The most that can be done is to arrive at an approximate relation between the cost of different services. It is a useful plan to obtain those approximations, but they should only be treated as an influence in determining tariffs, or much advantage to the community will be lost. In making calculations as to the cost of supplying any consumer, it is usual to take the cost for, say, a year's supply. Some period must be taken, but the cost of supplying any consumer varies from hour to hour, from season to season, and from year to year. Such factors as the distance from the supply works are necessarily disregarded. But the most important factor which is disregarded is the measure of development consequent upon supply to any particular consumer. It is a latent factor, but a very real one. It cannot be determined precisely but, unless its existence is realized, growth—the growth which is a consequence of wise tariffs—will be lost to the undertaking. Mr. Blaikie suggests consideration of the cost of service to selected groups of consumers, and Mr. Beauchamp to blocks of consumers. That is, I think, a step in the right direction. Mr. Blaikie, however, goes rather too far in his desire to pay regard to the value-of-service factor. At the bottom of column 2 on page 710 he defines the " value-of-service " theory as meaning " simply getting as much as possible for the goods, having regard to the possibility of competition." I do not like that definition. It would embrace profiteering, and profiteering by a municipality, under the protection of a monopoly, is, to put it mildly, a very distasteful operation. The only legitimate use of the influence of value of service is in the differentiation of charges in some measure according to such value, not in increasing the aggregate or bulk of such charges. Further, one consumer or group of consumers should never be charged at a low rate at the expense of others charged at a higher rate. Then, about the middle of column 2 on page 711, he says : " In the opinion of the author the value-of-service theory is the only one of practical value, and the aim of the management should be substantial profits, with an eye to future competition. In the case of public authorities these profits can be applied to various reserve funds or to the relief of the rates." I do not agree with that, and I do not think that the general drift of his paper is consistent with the expression of such a view. It seems to me that the aim of such an undertaking should be the realization of the greatest advantage to the public. The detailed administration of the undertaking should be directed towards the realization of that aim, including the compilation of tariffs. As to the distribution of that advantage, personally I am in favour of its falling into the hands of the consumers, the undertaking retaining only such profit as may provide prudent reserves and a normal interest and sinking fund on the capital employed. The consumers should not be taxed for the relief of the non-consumers. Mr. Beauchamp, on page 715 of his paper, says : " Unfortunately, in many places to-day a consumer who pays less than £5 per annum is a source of loss to the undertaking." I consider that that statement is apt to be misleading. It does not follow that consumers, the cost of supplying whom appears in the cost account-book to show a loss, are really a loss to the undertaking. If the increment cost of supplying them is more than £5 there is a loss, but it does not follow that because the £5 does not cover that consumer's equal or proportionate share of the capital, management, and administration charges of the undertaking, his supply involves a loss. It may be a profitable supply. The result of my investigations has demonstrated to me that all businesses must include amongst their transactions many which show a loss according to this restricted method of computation. Indeed, I believe that the best business can be realized only by deliberately departing from such a principle as that of equal profit from all consumers on the basis of equal share of cost (capital and operating).

Mr. W. J. Minton : As a meter engineer I must thank the authors for showing me the problems that are ahead. Mr. Blaikie, in my opinion, is trying to perpetuate the faults of accountants. As mathematicians we ought to refuse to adopt the rule-of-thumb methods adopted by the average clerk. The " pluses " given at the top of page 712, column 2, lead to error. As anyone who has had anything to do with allowance for meter error in accounts knows, the error is caused by taking percentages in the wrong order. The " plus " should be substituted by " multiply." I have on a former occasion shown that £100 + 10 % − 10 % does not equal £100. It would therefore be better to rewrite the figures on page 712 as " multiply by 0·666 × 1·1 × 1·15." That is more simple and involves only one calculation. There is another point to which I should like to refer : Mr. Blaikie divides consumers into two groups. The 6-day group, to my mind, could be called the one-meter group ; the 7-day group could be called the " multi-meter " group. It may sometimes be true, but not always, that inaccurate meters cancel each other out. Under the one-meter group falls the bulk supply, which is not mentioned at all. Bulk supply necessitates experts on the consumer's side who will see that the meter is accurate (or slow)—so there will not be a " fast " meter to cancel a " slow " one. In my opinion there should be a fourth clause added, called the " Meter Accuracy Clause." This meter accuracy should be obtained after a three months' run of the meter, or from the date when it was last repaired, and should be obtained once a year. It is worth the trouble when £50 000 or £100 000 is involved.

ADJOURNED DISCUSSION BEFORE THE INSTITUTION, 5 MAY, 1921.

Mr. A. N. Rye: Mr. Beauchamp's paper appeals particularly to me because I have to deal with numerous undertakings in small country and sea-side towns, which must depend entirely on the domestic load. One of the great problems that confront us to-day is how to obtain sufficient revenue per consumer, quite apart from the price per unit. The information in Mr. Beauchamp's paper and in Colonel Vignoles's communication (see page 733) seems to show that, for the small consumer at any rate, the maximum amount that is obtained per service is more important than the actual price per unit. The generating cost for these small consumers is trifling compared with the total costs when capital charges are included. My interest in the two-part tariff arose a good many years ago, when the metal-filament lamp was substituted for the carbon-filament lamp and the revenue from consumers began to drop very heavily. The company with which I am connected made very great efforts to develop other uses of electricity, and we adopted a two-part tariff, which was generally termed a contract tariff at that time. In one town this tariff in the course of three years became so popular that over 50 per cent of the total revenue from lighting consumers was derived from it. The principal reason that the contract tariff was so favourably received there was that it allowed small radiators to be connected to existing wiring in many cases and to be supplied through one meter. Unfortunately, with the altered conditions brought about by the war, our experience is that the two-part tariff is going out of use. I think the reason is an inadequate maximum price. In very few cases have we been able to get a maximum price allowed which really takes into account the changed conditions. Before the war the Provisional Order allowed us to charge, say, 8d. per unit. To-day after a great deal of effort and long delay we have perhaps got 10d. in some cases and 1s. in others—say, a 50 per cent increase. But we have found it necessary to increase the charges under the contract tariff in order to try to make ends meet, not by 50 per cent but by something more like 100 per cent, with the result that, in effect, we are trying to make the better-paying consumers pay the losses of the large block of consumers who are charged the maximum price per unit. They remain on the flat rate because we have no power to compel anyone to take the contract tariff or the two-part tariff if it does not suit his convenience to do so. Mr. Beauchamp has raised a most important point, namely, if a compulsory two-part tariff is impossible owing to legal restrictions, some consideration should be given, in the form of higher maximum prices, to those undertakings which operate a satisfactory two-part tariff. I had occasion to look up some figures in regard to one of our towns. They are not selected figures at all; the line of investigation was to take a certain number of consumers who happened to be in the same premises at two very widely separated periods of time, namely, 1905 and 1920. I took a dozen of those cases. In 1905 those consumers used approximately 9 500 units; in 1920 they used 5 000 units, the number of units per customer having dropped by one-half in that period due to the introduction of metal-filament lamps, to the Summer Time Act and, in certain cases, to the shorter shopping hours. Some of the cases relate to residences and others to shops; I took them quite indiscriminately. The price of 5d. per unit in 1905 in this particular group of consumers brought us in approximately £200. In 1920 the price had gone up to double that figure, viz. 10d., but the money received was only £3 more. I think that bears out the argument that tariffs for the small consumer to-day have to be considered very much more on the total amount of money per consumer than on the price per unit; and that argument, to my mind, is most forcibly illustrated by Colonel Vignoles's figures.

Mr. W. A. Gillott: It is only by closely studying the characteristics of the domestic load on the system that engineers are able to design a satisfactory tariff; by a satisfactory tariff I mean one that provides an adequate return to the supply authority and at the same time encourages the increased use of electricity for all purposes of lighting, heating and cooking, and is simple to understand. I think the last is essential. I am firmly convinced that the domestic load is only waiting for an attractive tariff to be put forward. A short time ago, on seeing a daily load curve of one of the London gas companies, I was struck by the enormous difference in the height of the peak on a Sunday compared with that on a weekday. It was very interesting to note that the output on the Sunday practically equalled that on a weekday, but in the case of the latter the period of the demand was naturally about 10 to 11 hours, whereas on Sunday the whole of the load occurred between 10.30 a.m. and 2.30 p.m. That proves the enormous amount of domestic use at midday, and the load comes on in the majority of cases when either the gas company or the electricity supply company can deal with it. I read before the Institution in 1914 and 1918 two papers* relating to electric cooking, in which I touched upon the question of tariffs. In each of those papers I gave a series of curves relating to the characteristics of the loads of various consumers, and they showed quite clearly, as far as the station supplying the energy was concerned, that the cooking load came on at the times the power station needed it, i.e. in the depressions in the load curve. The town I am referring to is Newcastle. Many tariffs were designed, and it was not until after four or five years' careful investigation that a reasonable tariff was established, and it was decided to make a fixed charge relative to the actual lighting consumption of the consumer. The watts per lampholder over some 6 000 installations averaged 40, and that formed the basis of the fixed charge, which was worked out at the rate of 6s. per lampholder per annum, chargeable upon 75 per cent of the lampholders installed, thus allowing for "convenience" lights. The possibility of half-

* "Electric Cooking and Heating in Private Houses," *Journal I.E.E.*, 1915, vol. 53, p. 42; and "Electrical Cooking as applied to Large Kitchens," *Ibid.*, 1918, vol. 56, p. 92.

watt lamps was foreseen and the fixed charge was based to compensate for that. The fixed charge covered the previous year's lighting units if charged at a rate less the equivalent of the low running charge, so that when the consumer used his lighting under the new system he paid exactly the same for light as he did in the previous year. The company was thus assured of its revenue, although it was offering a lower rate per unit on the running charge. It was only on the extra units that the consumer benefited, and I suggest it is the extra units that the supply companies need. As an illustration take my own case. At home I have roughly 20 kW installed, made up of lighting, heating, cooking and accessories. The maximum demand very seldom exceeds 4 kW, and the consumption is in the neighbourhood of 3 500 units per annum. The differences in the capital charges of the purely lighting consumer's services and meters compared with an installation similar to my own are so very small that the difference in the initial outlay is hardly worth consideration. The revenue the supply company receives from my house is approximately £30 per annum, whereas the revenue from the consumer next door, with a 2-wire service and a meter for lighting, is not more than £5 per annum. It is interesting to note that the diversity factor on the domestic cooking in the curves to which I have referred was somewhere about 9·1. As a result of the Newcastle tariffs, over 12 000 kW of electric cooking were installed, and the extra load was not noticed on the peak at all. Between noon and 12.30 p.m. a peculiar hump of about 2 000 kW appeared, and nothing further was seen of the cooking load until the next day, thus proving that the peak of the cooking coincided with the time when the works were shut down for the dinner hour. How the supply authorities base their fixed charge for the domestic tariff is mainly a matter of the local conditions, but an endeavour should be made to arrange the fixed charge so that the consumer can see its relationship to his own installation. We have seen cases where so much is charged per 100 sq. ft. of room area; in other cases the rateable value is used; in my own case it is a fixed charge on the number of kilowatts installed for lighting. These charges are understood and appreciated by consumers. The high diversity factor offered by electric cooking is such that one can afford to omit an extra kilowatt or fixed charge on cooking and heating appliances. The real aim of the electric supply authorities should be to increase their output, and the only way to do this is to offer a satisfactory and simple tariff, when all the load needed will be obtained. There is no doubt that the domestic load is the load of the future, and electrical engineers will soon realize that they must cater for it, as the public will demand electricity for cooking and heating in almost every case at no distant date. Thoroughly reliable cookers with every facility for quick replacement being available, there is no need to fear excessive maintenance charges.

Mr. W. R. Cooper: In Mr. Beauchamp's paper, with which I am very much in agreement, there is one point I should like particularly to support, and that is the importance of encouraging heat storage devices. For a good many years I have been advocating water-heating on this basis. The importance of water-heating on a small scale (apart from high load factor) lies in the fact that consumers will more readily adopt other electrical devices if the convenience of a continuous supply of hot water, which can be obtained electrically, is available. This is particularly the case in these days when there are so many domestic difficulties. Thus it is a question of expediency rather than the amount of revenue obtainable therefrom. It is impossible to gain this load on the ordinary tariff for low load factors, as the price becomes prohibitive. A two-part tariff, however, permits such a load to be handled, provided the running charge is sufficiently low. It may happen, however, that the running charge will not be low enough, and in any case dealings in tenths of a penny cannot be contemplated for the ordinary consumer. On the other hand, there is no difficulty in fixing, to a much greater accuracy, a quarterly charge for apparatus continually in circuit. Moreover, a quarterly charge can be adopted with any tariff, whether two-part or straight; the corresponding number of kilowatt-hours can be deducted from the quarterly bill and the remainder charged on the ordinary tariff, so that only a single meter is necessary.

Turning to Mr. Blaikie's paper, it will be readily agreed that the question of suitability of tariff is most important as an inducement to prospective consumers, but it is equally important that a tariff should be sound. There is no question as to the soundness of Hopkinson's basis for a tariff, provided that common-sense modifications in detail are introduced; but I do not feel convinced that the suggestion of dividing consumers into 6-day and 7-day groups is really sound. We must remember that once a station gives a supply it must be kept running, whether for light or power, and cannot be shut down during odd and inconvenient intervals. Although many single factory loads may not, on the average, run much beyond a single shift, the combined loads would necessitate two shifts in these days, even if the station were shut down at night time. It seems scarcely justifiable to suggest that the 6-day group would only require "roughly six shifts a week." This is surely penalizing the 7-day group. Finally, the author adopts a basis of one to two in favour of the 6-day group, both in labour and in capital. On this kind of argument a 5-day group would be let off still more lightly, and a factory running on two shifts would be saddled with a higher tariff because it would entail a second shift at the power station. This is surely fallacious. The argument of the author is all against the improvement of load factor through longer hours. In fact, the author goes so far as to say there is no gain in coal per kilowatt-hour by carrying the load factor beyond 35 per cent, and this is true if only a limited period per day is taken. We thus come to the penalizing of high load factor. Some differentiation in regard to capital is reasonable, because lighting consumers require a heavier expenditure on mains per kilowatt of demand than do power consumers, but I do not think that a distinction can be drawn in regard to station equipment on the ground that power consumers give an opportunity of employing large sets as against small ones. If small sets were used exclusively for

lighting and large sets for power in the same station, this distinction would be justifiable, but usually the same sets are used for both, and thus all classes of consumer benefit by the smaller outlay per kilowatt. Where the lighting consumer is at fault is that he provides only a small load at night, and such load as there is may be run at a high coal consumption per kilowatt-hour. But to urge that all 7-day consumers should be saddled with very high fixed charges is not justifiable. Unless we are to take a new view that off-peak load is of no value, then public lighting should be encouraged because it provides a night load. Domestic heating and cooking provides a good load, notwithstanding its 7-day characteristic, and equally so does electric traction. Electric lighting alone is undesirable. It appears to me that to claim all the virtues for the 6-day group leads to fallacious results, which may be demonstrated by asking any station engineer whether he would prefer to have a tramway load for six days a week or for seven. The reply must inevitably be in favour of the 7-day load. Why then saddle it with higher fixed charges per kilowatt of demand? With regard to coal, it is generally confusing to express fixed coal as coal per kilowatt-hour, because this must vary with the number of machines in use. It depends on the "utility factor." Similarly, it is doubtful whether "fixed coal" should be expressed on a maximum demand basis; for either the maximum demand varies without any variation in the fixed coal, or a small variation in the maximum demand may cause a considerable variation in the fixed coal. At one point in his paper the author proceeds to substantiate one set of figures for coal per kilowatt-hour against another set. But is substantiation necessary? The two can only coincide if no set is run for an appreciable time under-loaded. The difficulty is that the total fixed coal depends upon the duration of the load, and consequently cannot be treated satisfactorily on a kilowatt basis; in this respect it differs from capital charges. In fact, for many purposes, the "fixed coal" is variable and the running coal is fixed. The only coal item that can be logically treated on the basis of coal per kilowatt-hour is the running coal. The author proceeds to analyse coal consumption by the use of simultaneous equations. It is necessary to remember, however, that the use of such equations, if they are to be valid, depends upon the coal per kilowatt-hour remaining constant for each group in the two years taken. I doubt if this assumption can be made. This point is brought out by Fig. A, which gives the hourly characteristic of a station running three 1 000-kW sets, the running coal being 2·5 lb. per kilowatt-hour, the figure given by the author, but the "fixed coal" being taken as 1 000 lb. per hour for each set, instead of the author's higher figure (which seems unduly high). The characteristic line cuts the axis at A, B or C, depending on the number of machines running, and it varies abruptly when a machine is put on or taken off. The average for the year would be a line such as DE, assuming the conditions given by Mr. Blaikie. The upper part of the diagram gives the corresponding coal consumption per kilowatt-hour, and it is seen that this varies to a marked extent. If in one year the running were largely at a point G instead of F, or H instead of G, in the previous year, the coal per kilowatt-hour would be very different in the two years, and simultaneous equations would not hold. Another objection to the use of simultaneous equations in this way is that the percentage growth of an undertaking is often not very large. In that case we have to deal in comparatively small differences of large quantities, and the accuracy is doubtful. For example, if the growth is 10 per cent then an accuracy of 1 per cent in the initial figures becomes an accuracy of only 10 per cent in the final result. In many cases the growth is not as much as 10 per cent. Thus at West Ham in the year 1918–19 the 7-day total was 8·1 million kWh and the 6-day 30·1 million kWh. The corresponding figures for 1919–20 were 8·2 and 33·3 millions respectively. These lead to the result that the coal per

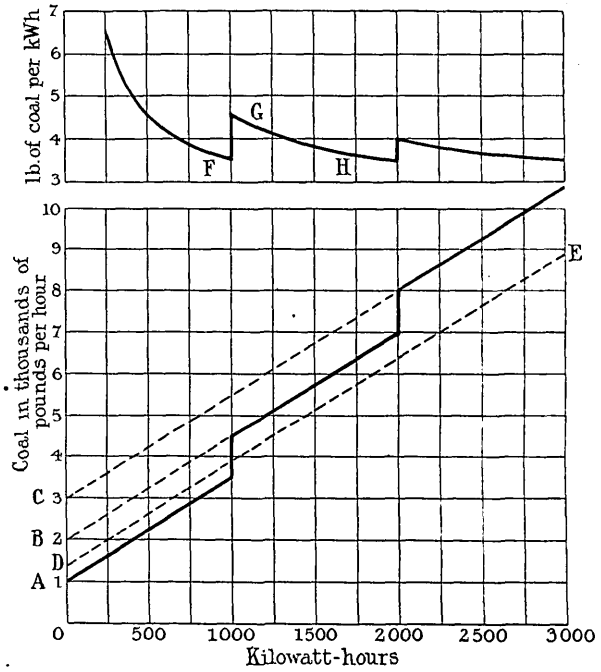

FIG. A.—Station characteristics (hourly).

kilowatt-hour for the 6-day load was approximately 2·57 lb. If now the output in 1919–20 had been 8·1 millions instead of 8·2, which would involve only a small percentage correction in the total coal, the calculated consumption changes from 2·57 to 2·96 lb., thus showing that the method must be applied with much caution, because small differences in the data may introduce large differences in the final results. Among the results obtained by equations I notice the figure of 40·7 lb. of coal per kilowatt-hour at West Ham, which seems extraordinarily high unless the conditions are very unusual. The figures in the tables indicate a high degree of accuracy, but I am not sure how this accuracy is demonstrated; between any two years that are taken for the purpose there can, of course, be no differences or errors. I think it would be a great advantage if Mr. Blaikie in his reply would give the working out of one of his examples so that the method

might be thoroughly understood and more exactly judged.

Mr. J. R. Dick: Mr. Blaikie has perhaps gone rather too far in discriminating between the two definite categories of 6-day and 7-day consumers, but the principle involved is quite sound. It is necessary to be more and more analytical with all the elements of costs and, although the actual figures obtained and the relative accuracy of the equations may be doubted, there is not the slightest question that a close scrutiny should be made of the labour, which is nearly all indirect in central station work. This element and the stand-by coal should be sub-divided and allocated in quite a different proportion from that given by the simple formula developed by Dr. Hopkinson and Mr. Arthur Wright, although it was quite sufficient in the early days to consider any costs in this class as equivalent to charges against investment. Another point I should like to comment upon in Mr. Blaikie's paper is his fear that, in the present abnormal monetary conditions, the effect of capital will become of diminishing importance in relation to the running and other charges. This, I think, is probably a mistake, because it is only a temporary phenomenon. The cost of plant, labour and coal are all, at any one epoch, functions of the prevailing currency, and when this becomes more stable the original relative proportions of all those factors in the general cost equation of electricity or of any other commodity will resume approximately their former values. It is evident from Mr. Beauchamp's paper that he is somewhat conscious of the danger of the heating and cooking load finally becoming exceedingly large compared with what it is now, in the by-product or temporary stage. If we want to be honest and deal with the matter on the basis of direct cost of production, we must face the time when the heating and cooking load will swamp the lighting load. In the distribution system, it will necessitate the adaptation of, and additions to, the existing network to deal with the heavier currents. For instance, in a suburban street with about 20 villas, it may be assumed that there will be a coincident maximum demand of about 2 kW each. If the street is 400 yards long, fed by a two-wire cable at 200 volts, it would require a 0·3-sq. in. section to keep within the 3 per cent limit of pressure-drop. Probably there is sufficient margin in the existing much smaller cable to take all the present heating and cooking load, but the possibility of heavier mains must be faced if this new business is going to preponderate, as we all hope it will. In order to overcome the excessive cost of the network due to heating and cooking loads it has been suggested that we should run all the distributors at a constant current-density; i.e. that Kelvin's law should be applied to the distributors as well as to the feeders and a constant current-density be maintained throughout, with a maximum loss of 10 or 12 per cent. It would be quite impossible to run the lighting on this system, and therefore there would be no alternative but to run two separate networks, although the duplication might mean less total costs. In considering the economy of working at constant current-density, it must be noted that the curve of efficiency representing Kelvin's law is very flat; that is to say, the efficiency as a function of the current density varies slowly, so that even when we have obtained a minimum value for the I^2R losses and the investment losses, we are still left with a very formidable amount of standing charges to be debited against the heating and cooking load.

Mr. W. L. Madgen: As is generally known, Electricity Commissioners have been appointed for the purpose of encouraging the supply of cheap and abundant electricity throughout the country. It would surely be thought that they would commence by administering a tonic to the distributing centres (by which I mean the business of supply in towns of varying sizes, some of them small) throughout the country, because, unless the local businesses are in a healthy financial state, it will be very many years before it will be worth while linking them up by main transmission lines. At present the business in these centres is not by any means in a healthy condition. In towns of moderate size, most of the middle-class members of the community have already been connected up at prices which yield some profit, but now that that market has been supplied those who are left are comparatively small consumers, while, as Mr. Beauchamp says in his paper, a connection which does not pay at least £5 per annum is a losing proposition. Consumers taking very much less than that are, however, being connected up even now and, as their number tends to increase, the profit made upon the class I first referred to is gradually being worked off, so that undertakings which are impelled to follow this blind policy must inevitably come to a financial deadlock. There is no antidote for that except some form of multi-part tariff, and there is not much sign of the Commissioners really grappling with this serious element in the situation. The President headed a representative deputation and urged the matter upon the Commissioners; he asked them to insert in what is called the No. 2 Electricity Bill a clause to authorize multi-part methods of charging, but they did not seem to be in favour of it, and we are still in a state of uncertainty as to whether they really mean to help us. I think there is nothing more important to the electric supply industry at the present time than that there should be some alleviation of the difficulties affecting the health of the distributing centres to which I have referred. I am concerned with a number of these small undertakings, and it is most difficult to get a young managing engineer to realize that he should not go out and get customers regardless of their probable consumption. It has to be forced upon him that it is more important to get existing consumers to increase the uses of electricity by employing auxiliary apparatus and by increasing their consumption, than it is to take on new consumers for lighting purposes only. The main elements in this matter are that the lamps in common use to-day consume only about $\frac{1}{2}$ watt per candle-power; we then have the Early Closing and Summer Time Acts which have largely restricted lighting during the summer months, so that shops and offices require little or no lighting during 6 months in the year. The position has become more serious for another reason. Since the country has been open to visitors from the Continent, it has been discovered

that, while the war was in progress, German and Austrian scientists had been working upon the improvement of the incandescent lamp and that lamps of still higher efficiency are on the horizon. The serious position that the supply authorities will be in when these lamps come into use will be readily appreciated. None of us can possibly take up the position of deprecating improvements in lamps, but it will be fatal to many of these undertakings if, before ¼-watt lamps arrive, a compensating form of tariff has not been authorized.

Mr. J. C. Elvy: We have heard very little so far about the actual registering instruments, meter manufacturers being significantly silent. Perhaps they do not regard Mr. Beauchamp's proposals seriously. While coal and other generating costs are calculated at under a fraction of 1 per cent, the condition of the meters, one of the most vital points on which the revenue depends, is frequently neglected. From the consumer's point of view I am entirely in agreement with Mr. Beauchamp. As the adoption of cooking, heating and power necessitates a larger meter, he will no doubt obtain some light free of charge. Say, for argument's sake, a consumer has a 200-volt 100-ampere direct-current meter; at 1/40th full load (2·5 amperes) it may be, at least, 10 per cent slow in registration, and most probably at 1/200th load (0·5 ampere) there is no registration at all. Some may contend that the meter may be 2½ per cent fast on the higher loads. Having been a Corporation official, I fully appreciate the meter engineer's difficulties. On our supply we had flat rate, demand-indicator rate, double tariff, factory rate entailing an office rate, and a shop-frontage lighting rate, which was a concession for contributing to the street lighting. There was also a kilowatt-demand rate plus a charge per unit. On some three-wire installations there was quite a large number of meters. By carrying on an active campaign in the direction of overhauling meters and introducing a further number of Bastian meters for small lighting installations, we obtained the following results at the outbreak of war: Efficiency of sales 87·09 per cent of units generated, compared with the average efficiency of 81·3 per cent of all other London municipal undertakings. With millions of units this becomes an important item. The effect on revenue would not be so marked with lower-priced units, but if larger meters were used the total lighting units might not be registered. The difficulty of providing a safety fuse has been mentioned, but I do not think this is insurmountable. Safeguard the one set of rising mains, and arrange sub-circuits so that the lighting circuits are lightly fused and the power circuits heavily fused, within the correct limits. We must cheapen the cost of installations somehow. With regard to current limiters, will they perform their functions satisfactorily if called upon to operate infrequently?

Mr. H. M. Sayers: Mr. Blaikie's division of consumers into 6-day and 7-day groups has been criticized a great deal, but I think it is fairly logical, although some exception may be taken to it, especially to the putting of traction undertakings among the 7-day consumers. This makes the maximum demand charge per kilowatt for traction several times that for factory use. It has been my lot on several occasions to ascertain what should be the proper price for traction supply, and I have generally had the satisfaction of convincing the arbitrator that traction supply should be properly charged at a lower rate than most industrial loads. Mr. Blaikie takes the coal consumption for no-load running as 30 per cent of the full-load consumption. That is too high. I have tested it a good many times and never found it more than 20 per cent, which makes a material difference. His hypothetical station is taken as running a 1 000-kW set for the lighting load, which has a maximum demand of 800 kW. This means that, for 7 or 8 hours per day, a 1 000-kW set is running on a load of 150 to 200 kW. No station engineer would do that if it were avoidable. Probably Mr. Blaikie will say that the figures I have extracted are illustrations, and that the correct figures can always be worked out for any given case. I agree that they can. The simultaneous-equation methods used by Mr. Blaikie are not explained in detail, so cannot very well be criticized. I have found similar methods very successful in showing the ratio of the standing coal and other costs to the output coal and costs. Mr. Blaikie says that no name has been given for the "plant kilowatt-hours." Colonel Crompton suggested a good many years ago the term "running-plant load factor," and I have used the term myself. It is an important factor in economical generation. As to Mr. Beauchamp's views on tariffs, is it any good for the electrical supply industry of this country to talk about a tariff on the basis of the value of service? I do not think there is the slightest possibility of our getting anything but tariffs based on costs, because the whole of the electrical supply industry of this country is more or less under legislative regulation and is not in the position of even a regulated monopoly. Therefore the basis of cost and a proper return on the capital seems to be a fair basis and the only practicable one. The question of tariffs for domestic use is difficult, but there is another difficulty in the way of the great extension of domestic use, and that is the cost of apparatus and its installation. We know how the gas companies have met that difficulty, and I suggest that the electricity supply undertakings should follow their example. They will never get a large number of small consumers for other than lighting purposes unless the small consumers can get the apparatus either free or at a small rental charge; and I suggest that the place of the fixed rate which we otherwise call the demand or assessment rate might very well be taken by such a rental rate. It would appeal better to the consumer, who is apt to look upon a demand rate as a payment for no tangible consideration.

Mr. W. B. Woodhouse: I endorse Mr. Beauchamp's claims for a two-part tariff. We are considering, as Mr. Dick pointed out, the sale of only one particular commodity, and it is a sale under peculiar conditions. We are bound to supply electricity for all purposes, and as we are subject to that obligation I think we are entitled to ask that we should at least be in a position to charge the cost of being ready to supply in every case. The sale of electricity represents an annual turnover of possibly 20 per cent per annum

on the capital employed. The importance of capital charges, where the turnover is such a small proportion of the capital invested, is enormously greater than when a commodity such as soap is sold. Therefore I think we are entitled to ask, in fact to demand, either that we shall be relieved from the obligation of supplying an unprofitable customer, or that we shall be entitled to put forward a tariff which will give us a reasonable return. The alternative is that the people in the electricity supply business will go out of it. We cannot possibly continue to face the prospect of supplying light at to-day's rates. Charges of 8d. and 10d. a unit are talked of. Neither 8d. nor 1s., nor 2s., will pay the actual costs in a great many districts, and I think that position has to be faced. I feel that Mr. Beauchamp's paper is most timely, and I hope it will have the desired effect. A point of interest, which is perhaps a little more abstract, is whether we are entitled, in selling our commodity, to distinguish between the classes of user, between the incidence of use, and so on. I think we realize that we must divide our consumers into classes. Mr. Blaikie has given us an interesting example of such a division, but we must be able to say that in a particular class we may be entitled to make a higher profit or be content to take a smaller profit than we do for another class. If we do not do that we cannot find money for development, and the growth of the industry will be retarded.

Mr. R. W. L. Phillips: Mr. Cooper's remarks about the simultaneous equations are correct to an extent when there are two simultaneous equations with the differences small and the values of the terms high. But it will be noticed that Mr. Blaikie has taken a period when the differences are very great. The method has been applied to two cases where the differences are small, and the very close results that he gets go to show, I think, that that is one way to segregate our costs. I think the principle, as laid down in Mr. Blaikie's paper, which does not depend upon a 6-day and 7-day group entirely, but on some form of grouping, should be carried on with some idea of getting a real idea of our costs, which should be ascertained before we frame any tariffs. I should like to endorse what Mr. Madgen said, that what we want now is a real licence in the way of tariffs. We are quite out of date, and I think that if some standard form of tariff could be devised the state of things in the industry would improve.

Mr. E. S. Ritter: I should like to criticize page 707 of Mr. Blaikie's paper. The cost of a kilowatt-year at 100 per cent load factor works out at about £34 and £17 for the 7-day and 6-day groups respectively. Why do the two figures differ so greatly, unless some essential factors have been neglected? If the method is correct it should stand the test I have given. Why has £5·88 per kW not been taken for public lighting and sewage pumping, instead of £21·08? Is not sewage pumping a power load? Both papers and the discussion have demonstrated that a charge per kilowatt-hour, i.e. a single-part tariff, is unsound, as it does not give the lighting consumer the benefit of a reduced rate for long-hour or other uses of his supply; not does it enable short-hour or small consumers to be supplied at a profit, two most essential conditions for the further development of the domestic side of the business. Some simple and universal method of charging for the supply which, by measurement or otherwise, takes into account the costs incurred, irrespective of whether the energy is used for lighting, heating or power purposes, is wanted in place of a multitude of tariffs.

The President (Mr. Ll. B. Atkinson): The discussion has emphasized the necessity and propriety of changing over definitely our methods of charging to multi-part tariffs. The meetings that the industry and the profession have had with the Electricity Commissioners have all resulted in this: we have received fair words from the Commissioners but nothing has happened. I do not believe for one moment that the difficulty arises with the Commissioners, because I am sure that they understand the necessities of the industry quite as well as we do. Unfortunately there are always political considerations in connection with our industry, and whether we shall be able to get past the political obstacles is another question. All we can do is to push the matter along as well as we can. The Institution has another conference of the interested parties to-morrow, which has been called with a view to put forward representations, if necessary, in connection with the Bill, and the discussion this evening will, in my opinion, strengthen the hands of all those who take part in to-morrow's conference. Mr. Madgen has suggested that we may have to consider ¼-watt lamps in the future. It may be that by the time these lamps are available something else will have occurred. I was told the other day on good authority that the problem of getting energy from the atom has been solved. If that is so, a single-part tariff will meet the case, but it will be a fixed charge, and whether people use much or little electricity will not matter.

Written Communications to the Discussion.

Mr. H. Bentham (*communicated*): Mr. Beauchamp's paper is undoubtedly a clear and concise exposition of the case for the two-part tariff and a higher minimum charge, both of which deserve the warmest support. Owing to the Early Closing and Summer Time Acts, practically all shop lighting whether large or small is now unremunerative in small undertakings at the prevailing statutory maximum of 8d. per unit. In one undertaking with which I am familiar 28 per cent of the domestic consumers have an annual consumption of 80 units or less, and naturally, as the lamp efficiency improves, this percentage will grow and become still more unprofitable unless the alterations suggested by Mr. Beauchamp can be prescribed as a remedy.

Mr. Blaikie's paper is most useful in many respects, but I am afraid many of his premises are incorrect. The proposal of a 6-day factory supply is certainly hypothetical; it is not practicable. I should like

Mr. Blaikie to hear the views of our power consumers on such a suggestion, for they are very annoyed when we cut off the supply for three or four hours to make a new connection, even in these days of trade depression. Frequently a guaranteed supply for week-end repairs has enabled us to supplant large private installations, and I have in mind a works power station of 1 500 kW where we might not have obtained the business but for the excessive cost of running their own plant for the small week-end repair load. Apparently Mr. Blaikie proposes to give the customer the benefit of the diversity factor. Such a concession would destroy the principal weapon possessed by supply authorities when competing for the supply to large factories requiring 1 000 kW or more, and this suggestion coupled with a price based on a 6-day supply (actually 6-day costs) would undoubtedly secure the business, but at such a figure that the load would be unprofitable. By the proposals outlined by Mr. Blaikie power consumers both small and large seem to be entitled to a supply at the same figure if classified in the same group. Load factor, however, does not entirely control production costs in these extreme cases, and the obtaining of a large power consumer is a much more competitive proposition than one of a smaller category. Our lighting load is 2 per cent of the total load, and I should like to know if Mr. Blaikie would deal with our case on the lines proposed. The fixed charges given on page 702 closely approximate to my experience.

Fixed Charges in 1920.

	Author's figures	Actual results
	Per cent	Per cent
Coal	32	33
Other charges (including depreciation)	42	36
Capital	26	31
Total	100	100

Mr. Blaikie's design of a basis for a perfect method of allocating the fixed and running charges does not appear very safe when ingenuous reasons are advanced at the end of his paper for departing from such a basis in the case of cooking and heating, promiscuous heating, small power consumers, etc., and the granting of tariffs to such consumers on more favourable terms.

Mr. S. E. Fedden (*communicated*) : The presentation of these papers emphasizes the difficulty of constructing a tariff applicable to all classes of consumers, and equally fair alike to consumer and undertaking. It will be readily agreed that a standing charge and a running charge, which is in effect a load-factor basis, is the ideally fair method of charging. The real problem is to find a satisfactory basis for the annual standing charge. The rateable value is satisfactory up to a certain point, but, when grounds and outbuildings are included, the annual charge is sometimes altogether out of proportion to the consuming capacity of the installation. The capacity of the installation is not a satisfactory basis, as it may easily and does actually restrict the adoption of fires, cooking ranges, and other apparatus with high ratings. Floor space—or rather part-floor space—of the premises to be supplied is another suggestion for fixing the annual charge, but in all the schemes put forward with this object the word "expediency" plays an important if not a predominating part, and the real object is to fix this annual charge at something which the consumer can afford to pay, and which will ensure to the undertaking an amount approximately equal to the revenue derived from the ordinary lighting consumer. If, then, this is the object, a two-rate system with an economic rate for lighting and a very low rate for additional uses would meet the case. There is, however, the objection of double wiring for the two rates retarding the use of small appliances with low ratings, which might otherwise be used on the lighting circuit. When larger appliances with high ratings are considered, the lighting circuits are of little value and it becomes necessary to install a special circuit. On the whole, it is perhaps preferable that the entire supply for every purpose should be at one rate. What I have now to say may not apply to undertakings where lighting or domestic use is the principal source of revenue; but where an overwhelming proportion of the units supplied are for power it will be interesting and instructive to examine arguments which are now being put forward in favour of a method of charging which is very aptly described as "Equal quantities of the same article at the same price." It must be understood, however, that I am not advocating the system, but merely putting forward the arguments used in its favour. It is asserted that the policy of municipalization involves the principle of equal service on equal terms to all citizens, and relies upon the working of the law of averages to enable this principle to be carried out. The load on a generating station is created at all hours of the day and night by the entire demand for every purpose. An undertaking does not supply light, or heat, or power, as separate and distinct commodities. It supplies units of electricity as and when required by each consumer. The name of the department acknowledges and confirms this statement of its functions. The cost of generating every unit at any given moment is the same to each consumer, and has no relation whatever to the use to which it is put when supplied. As a general statement it may be said that the demand for light, heat or power, is satisfied from the same cable. On many routes both the cost of the mains and the expenses of connecting the consumer have been extinguished by the portion of the sinking fund to which each customer contributes through the charges. Even should the customer prove to be a small and irregular consumer, the department is involved in no more trouble and expense than the actual cost of connection with the main, and save for this exception the small consumer at the worst is no more a disadvantage to the department than his neighbour who is not a consumer at all. The adoption of a uniform basis of charge to all consumers of electricity, with a sliding scale in favour of large consumers as far as this can be shown to be com-

COMPARATIVE FIGURES FOR THE YEAR 1920, RELATING TO (*a*) RESIDENTIAL DISTRICT, AND (*b*) INDUSTRIAL DISTRICT.

	(*a*) Residential	(*b*) Industrial
STATISTICAL.		
Mains—		
Street frontage (miles)	13·7	9·3
Total length laid (miles)	17·5	17·5
Weight of copper (tons)	33·3	101·0
Services—		
Number	613	492
Number of meters	794	669
Total capital cost of mains, services and meters	£30 035	£69 144
Consumers—		
Number	593	456
Per mile of mains street frontage	43·36	49·03
Per ton of copper	17·8	4·52
Per £100 of capital expenditure	1·97	0·66
Units supplied during 1920—		
Total	477 560	24 037 935
Per consumer	805	52 733
Per meter	601	35 931
Per yard of mains street frontage	19·8	1 468·6
Per ton of copper	14 341	238 000
Per £100 of capital expenditure	1 590	347 650
FINANCIAL.		
Revenue during 1920—		
Total	£6 693	£128 971
Per consumer	£11 5s. 7d.	£285 0s. 5d.
Per meter	£8 8s. 7d.	£192 15s. 7d.
Per yard of mains street frontage	5s. 6d.	£7 17s. 7d.
Per ton of copper	£201	£1 276 17s. 9d.
Per £100 capital expenditure on mains	£22 5s. 8d.	£186 9s. 4d.
Per unit supplied	3·365d.	1·288d.
Maximum demand	500 kW	10 000 kW
Capital costs—		
Generating plant at £13 per kW	£6 500	£130 000
Mains, services and meters	£30 035	£69 144
Total	£36 535	£199 144
Interest and sinking fund at 10 % *per annum*—		
Per annum	£3 653 10s. 0d.	£19 914 8s. 0d.
Per unit supplied	1·837d.	0·198d.
Distribution, management and rates—		
Per annum, at £6 1s. 6d. per consumer	£3 602 9s. 5d.	£2 770 4s. 0d.
Per unit supplied	1·8d.	0·028d.
Income tax (*divided proportionately to revenue*)—		
Per annum	£335	£6 448
Per unit supplied	0·168d.	0·066d.
Generation—		
Per annum, at 0·81d. per unit	£1 501 10s. 3d.	£81 128 0s. 7d.
Per unit supplied	0·81d.	0·81d.
SUMMARY.		
Cost per annum—	£ s. d.	£ s. d.
Generation	1 501 10 3	81 128 0 7
Distribution, management and rates	3 602 9 5	2 770 4 0
Income tax	335 0 0	6 448 0 0
Interest and sinking fund	3 653 10 0	19 914 8 0
Total	9 092 9 8	110 260 12 7
Revenue per annum—	6 693 9 8	128 971 13 8
Loss	2 399 0 0	—
Profit	—	18 711 1 1
Cost per unit—		
Generation	0·81d.	0·81d.
Distribution, management and rates	1·8d.	0·028d.
Income tax	0·168d.	0·066d.
Interest and sinking fund	1·837d.	0·198d.
Total	4·615d.	1·102d.
Revenue per unit—	3·365d.	1·288d.
Loss	1·250d.	—
Profit	—	0·186d.

mercially sound, is a just and equitable apportionment of the working costs and capital charges of a municipal electricity undertaking. Even in the case of the largest consumers it cannot justly be held that the generating costs of the last thousand units are any less per unit than the first thousand. The argument employed to justify a high price to lighting consumers, based upon the alleged maintenance of stand-by plant, is not backed up by any definite information as to where such special reserve plant for lighting is located or what it consists of. A sudden demand for current to produce light is no more of a tax upon the department than a sudden demand for power or any other purpose, and any possible demand for lighting under any conceivable circumstances can bear but small relation to the productive capacity of the generating station. From every point of view it will be in the interests of the department to establish an equitable system based upon the actual character and bulk of the commodity supplied, irrespective of the use to which it is put, and the adoption of such a system will be a long step towards the realization of the hopes which actuated the corporation and citizens in the municipalization of the undertaking. A large proportion of commercial and manufacturing consumers of current for lighting are also users of current for power and heating as well. The absurdity of a differential charge in such cases is self-evident, and a system of computation which requires three different meters to measure a supply of exactly the same commodity in the same building cannot be considered to be an example of modern labour-saving organization. The ideal domestic supply ought also to include the use of current for all purposes, whether light, heat or power. Under existing rates not only can every conceivable inequality of charges be found side by side, but the alleged impossibility of supplying current for lighting at the same price as current for power seems to present no insuperable difficulty. Practically the whole of the enormous development during the past few years has been in the interests of power users, who might fairly be expected to accept the principles of municipalization together with its advantages and to recognize the principle of equal service for equal charge, which is at the least the ideal of all national, municipal and other statutory undertakings which are carried on for the common good. While it is gratifying to observe the enormous expansion as an adjunct to industrial enterprise, it must not be forgotten that one of the objects for which an undertaking exists is the betterment of the condition of the community at large, and it can hardly be doubted that a rearrangement of the charges for current on the basis of equal quantities of the same article at the same price would remove an existing injustice of no small degree, and give widely-felt encouragement to the more universal use of electricity for every suitable purpose.

With the object of making a comparison with reference to the cost of distribution for lighting and private supply, with that of a supply principally for power and furnace use, I have taken two districts of precisely the same area, i.e. $1\frac{1}{2}$ square miles in each case. Full details are given with reference to the cost of distribution of the supply in each of the districts, the first being a purely residential district, and the second a manufacturing district. In each case the cost of producing the current, including administration charges, has been added. It will be seen that the total costs of production and distribution in the residential district are 4·615d. per unit; and the cost of generation and distribution in the industrial district 1·102d. per unit. The average revenue from the residential district is 3·365d. per unit, which being deducted from the cost of production and distribution set out above shows a loss of 1·250d. per unit. If the maximum price for electricity be reduced to 2d. per unit, the loss will be increased to 2·6d. per unit. The revenue from the industrial district is an average of 1·288d. per unit.

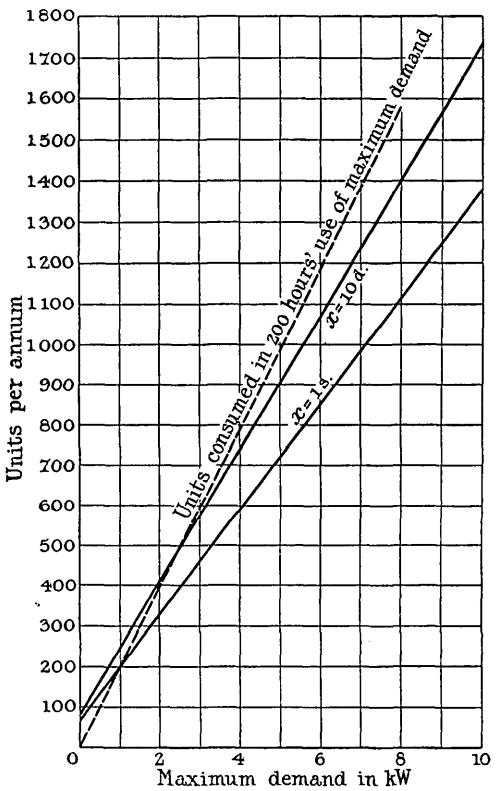

FIG. B.—Diagram showing minimum number of units at xd. per unit that must be consumed to cover standing charges.

Deducting the cost of production and distribution—1·102d. per unit—there is a profit of 0·186d. per unit in this case. Interest and sinking fund in respect of capital outlay are charged in each case. The cost of production of the current as it leaves the power station is charged at the same rate in each case, viz. 0·81d. per unit, but this is unduly favourable to the residential district, as it is obviously more economical to produce the unit with an output of 24 million units spread equally over each day than to produce the unit with an output of half a million units during the hours of lighting, which occur principally during the winter months. The supply for a residential district is required only for an average of 3 hours per day, whilst in the case of an industrial district the supply is required

for an average of 8 hours per day throughout the year. The result of the investigation goes to show quite conclusively that the loss on the cost of current supplied to the residential district has to be borne out of the profit received from the industrial district. The revenue figures used in both cases are for the full year ending 31st December, 1920.

Lieut.-Col. W. A. Vignoles (*communicated*): I entirely agree with Mr. Beauchamp as to "the urgent necessity of accepting the principle of multi-part charging for electricity supply." With the increased cost of mains and services, the cost of "being ready to supply a consumer" is a very serious problem, and one which presses very hardly on undertakings distributing electricity in districts where small houses predominate. Assuming that a consumer pays the whole cost of the service line on his premises, the actual cost of supplying him, without allowing any margin for profit, reserve fund or for plant the output of which is unsold, is, in Grimsby:

	£	s.	d.
(*a*) Fixed charges on service and mains per consumer	2	12	6
(*b*) Standing charges on plant, etc., per kW of maximum demand	5	10	0
(*c*) Cost of generation (average) per unit ..	0	0	2

These figures apply to short-hour consumers only, and the cost of generation is therefore taken as the average; it would be more correct, and would be necessary if long-hour consumers were being considered, to divide (*c*) into running and standing charges; this would decrease (*c*) but would increase (*b*). To illustrate the incidence of the above figures I give Fig. B, which shows the units that must be purchased by a consumer for a given maximum demand in order to cover fixed and standing charges. This figure also shows that, however small the consumer's installation, the undertaking will not be able to cover these charges unless he consumes about 100 units per annum. In 1920, 235 consumers, or 9 per cent of the total number connected in Grimsby, used less than 100 units; and out of 131 consecutive consumers in a main street, 51 (39 per cent) used less units than are shown on the diagram to be necessary to cover the fixed and standing charges. Considering "short-hour consumers" as distinct from "small consumers," it will be found that, with early closing and Summer Time, the time during which artificial light is required, in premises where daylight is not obstructed unduly, is approximately:

Offices: 100 to 150 hours per annum.
Shops: 200 to 250 hours per annum.

Fig. C has been drawn from the figures given above, and shows the relation between the cost per unit and the number of units sold per annum, (*a*) with a varying maximum demand, and (*b*) a varying number of hours' use of maximum demand. In considering this figure, it is to be noted that 28½ per cent of the total number of consumers in Grimsby use less than 250 units per annum. The curves show that the cost of supplying a consumer using light for 100 hours, and consuming 250 units per annum, is 18d. per unit, and that this rises to 21d. per unit if the consumption is 100 units per annum, as against a maximum statutory charge of 10d. per unit. The shape of the curves shows the

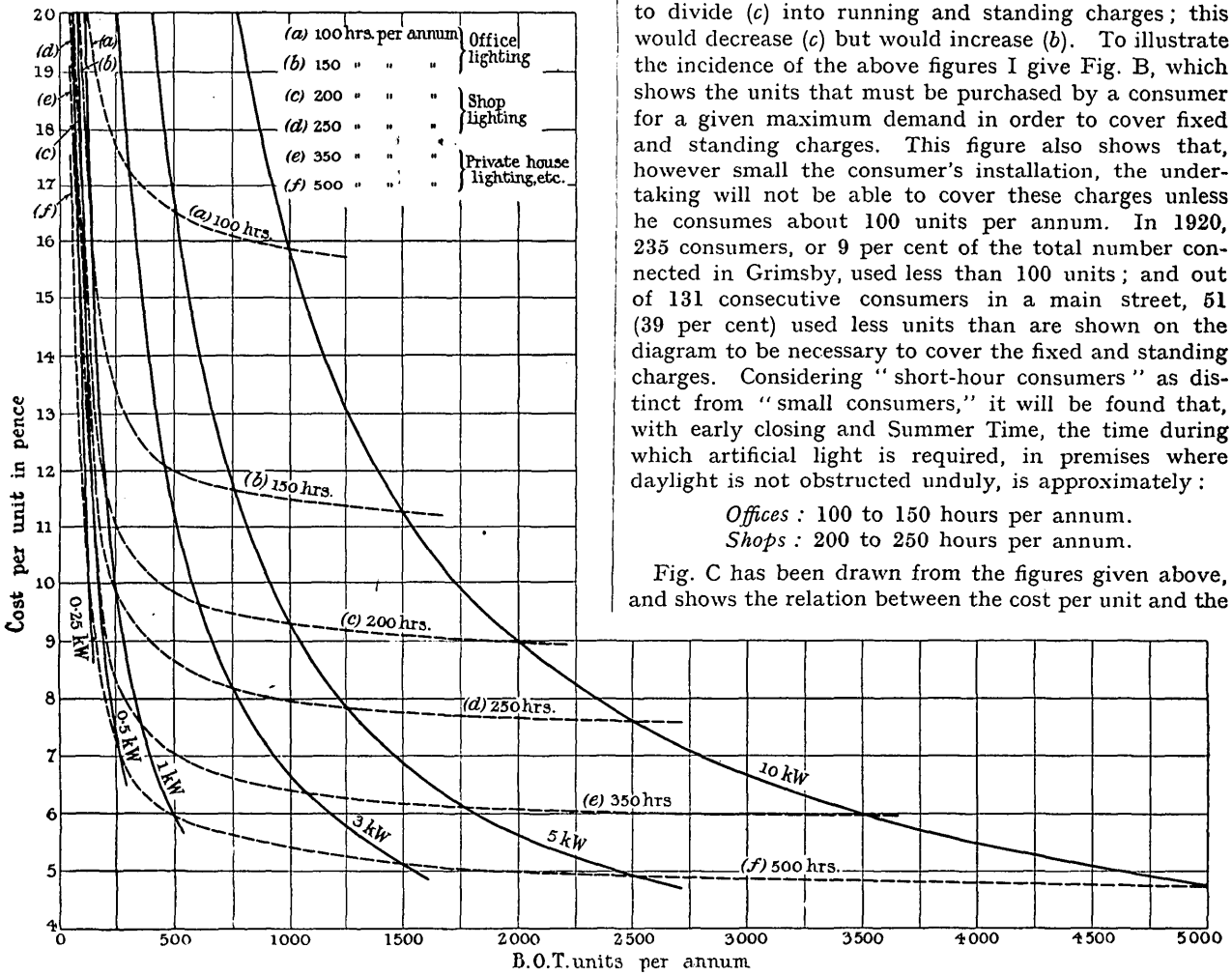

FIG. C.—Curves showing the cost per unit of supplying electricity to consumers at varying rates of maximum demand.

The dotted curves are derived from the others and show the cost incurred for any particular number of units consumed for maximum demands varying from 0·25 kW to 10 kW and maintained for the periods shown.

impossibility of fixing any rate per unit that would be fair to all classes of consumers; a two-part tariff appears to be the only solution. The figures make it clear that a loss is being made on the supply to certain consumers, which loss has to be made up by profits obtained from other classes of consumers. The general position in the electricity supply industry appears to be that charges for electricity supplied to the long-hour consumer cannot be further increased; that we have reached, or in some cases have passed, the price which the long-hour consumers are willing to pay, and that it is of the greatest importance that the small and short-hour consumers should cease to be a burden on the consumer who is the mainstay of supply undertakings.

Mr. J. R. Blaikie (*in reply, communicated*): Mr. Wright asks for a more detailed explanation of the proposal to divide consumers into 6- and 7-day groups. Perhaps the historical account of this development will prove to be of interest. During four consecutive war years at Bedford the steaming conditions were fairly uniform, but remarkable changes in the annual consumption of coal and units sold were observed. These changes could not be accounted for by variations in load factor, and an explanation seemed to lie with the alterations in the character of the demand brought about by war conditions. In the first year there was an abnormal demand for lighting, owing to large numbers of troops being quartered in the town. This was followed by a severe suppression of lighting, both public and private, as a precaution against air raids, and at the same time there was a rapid expansion in the demand for power for munition works. The actual figures of coal consumption and output are as follows:—

Year	Units Sold	Tons of Coal Consumed
(1) 1914–15	3 065 682	11 429
(2) 1915–16	3 357 392	10 634
(3) 1916–17	4 115 733	11 565
(4) 1917–18	5 462 911	15 650

As explained in the paper, experiments were made with simultaneous equations; and a subdivision of the output into two groups, viz. 6- and 7-day demands, gave values of coal consumption per unit from which the coal bill could be reconstructed to within $2\frac{1}{2}$ per cent for each of the four years. A similar result was found by experimenting roughly with the figures from other undertakings, and is also observed in the early history of the Bristol undertaking many years prior to the war. The case was developed chiefly with the object of obtaining an intelligent idea of the rates of increase to be applied to various classes of consumers, necessitated by the enormous rises in the price of coal per ton. With the facts fairly well established, the hypothetical case was constructed, which I think explains the matter in a satisfactory manner and proves that broadly similar results must occur in every steam-driven undertaking. It is pointed out that in early days with cheap coal this effect was negligible, or did not arise when the supply was entirely for lighting. Mr. Dick agrees that this is so, and that at the present time it is desirable to subdivide the standing coal. Having divided the output in this manner to suit the coal it was found that, incidentally, the same grouping was suitable for subdivision of other charges and capital charges, and, further, that protective clauses could be based on the price per ton of coal. Both Mr. Wright and Mr. Dick question the justification in my application of the figures showing that at the present time capital charges in existing undertakings are about 35 to 40 per cent of the whole fixed charge, instead of 50 per cent or more as in pre-war days. They point out that this is a temporary effect. I quite agree, but in these disturbed times, when it may be necessary to correct tariffs every 6 months, it is important to have a clear conception of the costs at the moment. It is also probable that a large volume of pre-war capital will remain active for perhaps 10 years, and tariffs might be revised, say, once in 3 years under normal conditions. With this general explanation, I will now take the comments of speakers in the order in which they occur.

Mr. Wright makes a series of observations which provide material for a lengthy discussion in themselves. With regard to (*a*), I take it that Mr. Wright desires to emphasize the fact that small intermittent users contribute a great deal to the diversity factor, and should therefore share a larger proportion of the diversity-factor benefit than steady long-hour consumers. This might be effected by adjusting the fixed-charge rate to benefit the deserving classes. Observation (*b*) appears to require fuller detail. I presume that (*c*) is in the form of a meter or service rent, and I suggest that the policy must be governed to a large extent by the practice of the local gas competitor. With regard to (*d*), if, as Mr. Wright suggests, the profit should be chiefly derived from the running cost, surely the good-load-factor consumer is unduly taxed. I think that, if the traffic will bear it, it is more satisfactory to aim at the same percentage profit on the total cost of the units supplied to each consumer or to groups of similar consumers. I understand Mr. Wright to mean by (*e*) that a power-factor clause should apply to the power factor measured at the time of maximum demand. With this I quite agree. If a consumer is charged on a load-factor basis and runs his plant intermittently, he will have a low load factor and a low average power factor. He pays for the low load factor and, in doing so, hires the use of the plant serving his maximum demand. If he occupies this plant at intervals with wattless current he only tends to lower the diversity factor of the whole system, and the loss in diversity factor is usually shared by all consumers.

Mr. Purse criticizes the 6- and 7-day grouping chiefly from the point of view of capital. I gather that he agrees from the coal standpoint, or at any rate he appreciates the conclusion that lighting consumers require a larger share of the stand-by coal than the load factor indicates. With reference to shop lighting, I am convinced that it is not nearly so bad as the Hopkinson analysis leads us to suppose. The capital outlay on

mains is very largely influenced by the density of the demand. In the figures contributed by Mr. Fedden it will be seen that the distributing system costs about £60 per kilowatt of demand in a residential area, as against about £7 in an industrial area. I think it will be agreed that in a shopping area the density of the demand is much higher than in a residential area, and therefore the cost of mains will be considerably lower per kilowatt demanded. During the war, in many cases, shop lighting was suppressed and the plant was available and used for power purposes. If shop lighting were really as disastrous as is usually supposed, there should be a marked improvement in the finances of the year when it was removed and replaced by power. In Bedford no such result was observed and I shall be much surprised if any undertaking can trace any benefit from the omission of the shop-lighting load. Mr. Purse draws certain conclusions from the Bedford figures. I should point out that these figures are peculiar to the area and the character of the demand. They are not given as typical, but merely as a practical example carried through to a balance sheet. I may say, however, that this system applied to a series of Bedford accounts appears to fit the financial results uncommonly well, showing, for example, that the tariffs for power were a little too close to the cost of production and, therefore, that the financial result for the year depended on the fortunes of the lighting section. With reference to traction, it is probable that a traction load should be treated as a combination of the two groups; as a 7-day consumer, the average Sunday output would be multiplied by 365 (in which case it would have a very high load factor), and the balance would be considered to be a 6-day consumer. As the meters are read daily at the generating station, there would be no difficulty in this subdivision. It is also possible that some adjustment should be made on account of the number of units sold being the same as the units generated. In the majority of cases meters are placed at the supply end and not at the delivery end of the feeders.

Mr. Cowan, I am glad to find, generally endorses the views expressed in the paper as to the value of service, as a principle in framing tariffs. The points of difference appear to be my tendency towards profiteering, and the disposal of profits. The charge of profiteering is met by a paragraph on page 711 commencing "Having regard to the statutory limitations." The limitations in mind are those contained in the Provisional Order, section 55, headed "Application of Moneys received," which provide for a reduction in the price charged after certain specified profits have been obtained. From the same section I also draw the conclusion, in the case of public authorities, that the profits should be distributed amongst the ratepayers as a whole, and not amongst consumers, chiefly because the ratepayers are responsible for any loss on the undertaking. Incidentally, I believe that a strong financial position in the undertaking, having thereby no anxiety in extending mains or replacing obsolete plant, is also in the best interests of the consumer.

Mr. Minton draws attention to the inaccuracies that arise from the custom of expressing small differences as plus or minus percentages. I quite agree that a correction factor is better for instruments and precise work, but as employed in this paper I think that the popular method is more effective.

Mr. Cooper's criticism shows much careful consideration of the paper. After studying his comments I feel that there is really a very small difference in opinion. He says: "There is no question as to the soundness of Hopkinson's basis for a tariff, provided that common-sense modifications in detail are introduced." I thought that I had expressed precisely the same opinion, and it is therefore only a question as to what the modifications should be. With reference to the fixed coal, Mr. Cooper finds many difficulties, but he shows that a resultant can be obtained from quantities that vary hour by hour, and I feel sure he will agree that over long periods the fixed coal can be ascertained with some confidence. On the question of the figures used in the hypothetical case, perhaps Mr. Cooper has overlooked the practice used throughout of dealing with units sold and not with units generated. In this case the units used for iron losses in transformers, meter shunts and other continuous losses, all augment the fixed coal items. For a station having the loads suggested, I think that an overall consumption of 6 lb. per unit sold is not unreasonable. However, other figures may be substituted and broadly similar results will be found. The point I particularly wished to make is that the 7-day load, which is chiefly lighting, requires more fixed coal per kilowatt of demand than the 6-day load, which is chiefly power. Perhaps this will be apparent by considering the shape of the daily load curves. The familiar lighting-load curve resembles mountain peaks, whilst a purely power load is in rectangular blocks. It is possible to have two such load curves each having the same load factor, but there will be little doubt as to which requires more fixed coal. A tramway load has both characteristics and is therefore likely to require an amount of fixed coal somewhere between the two. The use of simultaneous equations is doubtful, I admit, and this is acknowledged in the paper. The results must be checked by other means. The coal, at Bedford, is checked by the observed Sunday consumption and also by the close reconstruction over 4 consecutive years. The wages item is checked by an entirely different form of analysis. Only as regards capital charges is there no check, but the quantities have large variations year by year, so that the results may be more reliable. Mr. Cooper agrees that some differentiation in regard to capital is reasonable. With regard to station equipment, I suggest that if lighting were the only load the development of the station would be marked by the addition of comparatively small units over lengthy intervals. With power the advance takes place in larger steps and justifies the installation of large units. The power load, therefore, is the reason for installing large units and deserves an advantage in the price per kilowatt of plant. On the point Mr. Cooper makes by asking any station engineer if he would prefer a tramway load for 6 days a week or 7, let us first suppose that the station supplies tramways only. If the station runs 7 days a week, undoubtedly the load factor will be higher. Now as to the three items of the total cost.

(1) Will 6- or 7-day load in tramway service give the lowest cost of coal per kilowatt-hour? *Answer*, 6-day.

(2) Will 6- or 7-day load give the lowest charge in wages per kilowatt-hour? *Answer*, 6-day.

(3) Will 6- or 7-day load give the lowest charge in capital per kilowatt-hour? *Answer*, 7-day.

It depends, therefore, on the relative costs of coal, labour, and capital where the advantage lies. In existing stations, under the conditions prevailing at the moment, coal and labour predominate. If the supply is from a general system the advantage may depend on the sizes and numbers of units of plant that the tramway load may require. That is to say, how much additional coal and how much additional labour. Mr. Cooper is under a misapprehension in reading 40·7 lb. of coal per kilowatt-hour at West Ham. This figure is only a ratio, assuming that the 6-day load was 10 lb., which figure was adopted as a common basis. I have much pleasure in giving the details of one of the examples of simultaneous equations.

	6-day Units Sold	7-day Units Sold	Tons of Coal
1915	1 871 456	1 194 226	11 429
1916	2 383 756	973 636	10 634
Average	2 127 606	1 083 931	11 031
1917	3 309 075	806 658	11 565
1918	4 493 140	969 771	15 650
Average	3 901 107	888 214	13 607

and that owing to the large amount of pre-war capital still active the rise in the capital component will be slow.

Mr. Sayers finds the division into 6- and 7-day groups fairly logical, but he raises questions very similar to those of Mr. Cooper. Perhaps the reply to Mr. Cooper will cover some of these points. I am glad to hear that Mr. Sayers has been very successful with the use of simultaneous equations. Provided that there are material differences in the quantities, and the results can be approximately checked by some other method, this method may be very useful. I think that Mr. Sayers will agree, on further consideration, that the modern practice of installing a small number of large units shows an advantage both in capital cost and also in steam consumption, notwithstanding the large waste of kilowatt-hours run that may occur in some districts. With reference to the term "running plant load factor," I presume that this is the same as plant load factor. Mr. E. Tremlett Carter in "Motive Power and Gearing," published in 1896, defines it as follows:—"The plant load factor, or the ratio of work done by any unit in any given time to the total work it could have done had it worked at full capacity during the time without intermission." Various applications of plant load factor are used in many ways, but chiefly, I believe, in daily records to see how the plant available fits the load, and to watch this influence on the coal consumption. The factor I had in mind is over the whole year, as in the usual case of load factor, and is the ratio of the units sold to the maximum possible output of the plant during the hours it is running. By the way, many of these terms, including load factor, seem to be lacking definition by a standard authority.

Mr. Woodhouse confirms the view that tariffs should

it is very doubtful whether any other form of power could do the work at a lower rate. In these circumstances there can be no objection to the rate. If the sewage pumping were a much larger user, then the fixed charge of the 7-day group would be lower and the rate per kilowatt-hour with the same load factor would also be lower.

Mr. Bentham's case of a power consumer who found it too costly to run his own plant on Sundays is a valuable illustration of a point I have been trying to make. If the consumer ran his plant on Sunday his load factor would be higher and, according to general belief, therefore his cost per kilowatt-hour should be lower. Apparently, this is not so. I believe that something of the sort is experienced in most power houses. Does not Sunday running tend to spoil the records? It is a common argument to say that "a power house has to run on Sundays anyhow, and the extra cost of taking on load is so small that we can do it at a specially low rate." There might be something in this argument if a low rate for power on Sundays attracted consumers, but I think it will be admitted that in practice nobody runs his works on Sundays if he can avoid it. If he must run his plant on Sundays he would pay a little more for the current. With plant running at uneconomical loads and extra wages it will probably be admitted that the costs per kilowatt-hour are higher on Sundays than on any other day, and in such case it seems absurd to sell current at the same or even a lower rate and charge the losses to all consumers. The reason that the power house has to be run is because certain consumers require a supply, and it seems logical to try to make such consumers pay the extra costs. Mr. Bentham says it is not practical in a factory. That is probably correct; it might cost more to ascertain the Sunday consumption than it would be worth. On the other hand, tramway loads and bulk supply can be easily allocated; also large groups of residental consumers and public lighting can be classified as 7-day loads. If an important volume of supply can be fairly charged on a 7-day basis there is no occasion for what Dr. Johnson calls "needless scrupulosity" in the case of repairs in factories, which are essentially 6-day consumers. It is also possible to construct tariffs that do not follow the costs too rigidly, by putting all the profit on the running charge. In this case the extra load factor due to Sunday running gets very little advantage. In Mr. Bentham's case with only 2 per cent of the total load used for lighting, some other form of grouping might be better. It depends, of course, on what his Sunday load is, and the possibility of identifying a substantial amount. I am glad to see that he finds similar proportions in the fixed charge to those given in the paper. With reference to heating, etc., the proposals put forward have no pretence to be perfect. I think that Mr. Bentham appreciates the idea of studying the fixed charge and, possibly, of establishing groups having different fixed charges, with a view to discovering the costs and the effects of changes in the price of coal and rates of wages. As for tariffs, I think I have made it clear that they should not be based too rigidly on the costs. The construction of a Hopkinson form of balance sheet is the principal object of the analysis.

Mr. Fedden's communication and figures are a most valuable addition to the discussion. With an overwhelming amount of power, which is probably nearly all in the neighbourhood of 20 per cent load factor, differentiation on a load-factor basis becomes almost unnecessary. That is to say, if we can assume that each consumer has a load factor of 20 per cent we can at once quote a flat rate. But it requires too much imagination to suppose that small domestic users have a load factor of 20 per cent or anything like it, and, unfortunately, the costs increase very seriously with decreasing load factor below this point. Still, with a very large bulk of power it may be justifiable to temper the extreme penalties of low load factor, and perhaps Mr. Fedden has this in mind in disregarding standing coal. With the remaining figures I have drawn up a comparison with the findings of the Bedford case. Broadly speaking, the 7- and 6-day groups in Bedford are very similar to the residential and industrial areas of Sheffield.

	Bedford.				Sheffield.			
	7-day Group		6-day Group		Residential		Industrial	
kW Demanded	762 kW		1 038 kW		500 kW		10 000 kW	
	Total	Per kW of Demand	Total	Per kW of Demand	Total	Per kW of Demand	Total	Per kW of Demand
	£	£	£	£	£	£	£	£
Coal	3 493	4·58	634	0·610	—	—	—	—
Other charges	5 424	7·125	1 412	1·362	3 937	7·86	9 218	0·922
Capital	4 530	5·94	3 072	2·959	3 653	7·3	19 914	1·991
Total	13 447	17·645	5 118	4·931	7 590	15·16	29 132	2·913
Ratio	10 to 2·8				10 to 1·94			

Comparing the results it is interesting to note that the relative rates between the two groups are more pronounced in Sheffield than in Bedford, both in "Other charges" and in "Capital." The greatest difference is in capital charges, but the methods employed are entirely different. Mr. Fedden takes the aggregate capital cost in each case and charges 10 per cent on the capital. In order to obtain a Hopkinson balance sheet I took the actual capital charges for the year, which of course do not include charges on loans that have been extinguished. But probably the difference is due to the very much greater divergence in the size of consumers of the two classes in Sheffield, in which case there appears to be a satisfactory comparison between the two undertakings. Other features in Mr. Fedden's figures are very astonishing and of great interest; for example, it will be seen that the capital cost of mains, services and meters amounts to about £60 per kilowatt of maximum demand in the residential area, and about £7 per kilowatt of maximum demand in the industrial area. In view of the fact that the two areas are of a fair size it may be justifiable to regard them as representative of the mains system in Sheffield, and to deduce values for the two principal factors governing the cost of mains, viz. length and current capacity. Let C = capital cost; L = length of street frontage in miles; D = maximum demand, and let a and b be constants.

$$\text{Then } C = aL + bD$$
$$£30\,035 = 13{\cdot}7a + 500b$$
$$£69\,144 = 9{\cdot}3a + 10\,000b$$

from which we obtain

$$a = £2008{\cdot}4, \quad \text{and} \quad b = £5{\cdot}046$$

a represents £1·14 per yard of street frontage, and b represents £5·046 per kilowatt of maximum demand on the system.

If these figures are reliable, there is a basis for a multi-part tariff which takes into account the very important factor of length of mains. The consumer might be charged

	£	s.	d.
On account of frontage, at per yard ..	—	—	—
On account of maximum demand, mains and generating plant, at per kW ..	—	—	—
On account of distribution and administration, per consumer	—	—	—
On account of electricity, at per unit ..	—	—	—
Total ..	—	—	—

that is, adopting Mr. Fedden's treatment of generating charges, etc. Bills presented in this form may appear to be complicated, but if there is any merit in educating the consumer it is surely worth the trouble in making out the bill in this form, and advantageous to tell him the same story at least four times a year. In the happy event of multi-part tariffs being legalized, it might be convenient to raise any one of the items as required by publishing a short notice.

Colonel Vignoles's communication hardly comes within the scope of my paper, which is chiefly concerned with the analysis of costs. I regret, therefore, that he omits the particulars on which the data used are founded. I think, however, he will agree that if any logical system can be devised for increasing the portion of the charge which is due for service, and consequently for decreasing the charge per kilowatt of demand, such charges would offer greater inducements for consumers to install small heating apparatus. The form of tariff sketched in the reply to Mr. Fedden will illustrate the point. The effect of a heavy direct tax, per kilowatt of demand, as in the original Hopkinson tariff, is referred to in the paper.

Mr. J. W. Beauchamp (*in reply*): With regard to Mr. Arthur Wright's remarks, rebates have been given in relation to total consumption, and frequently have been too large, e.g. where an increased consumption has not indicated an increased load factor. The Hopkinson theory with the amendments proposed by Mr. Wright is generally accepted as a sound basis of charging, but are we bound or even able to continue to apply it to each individual consumer or must we be content if it applies to groups of small users, leaving us free to charge individuals by simple methods which may in practice conform to Hopkinson principles over the average results obtained? If it be agreed that for any further large advance in electrification we shall require "salesmanship" in the widest sense of the term, including not only educative advertising but the supply of wiring and apparatus on easy terms, such provisions are not encouraged by the principle of selling on a purely cost basis. The idea that the "cost of supply" must fix the "charge for supply" has been largely responsible for the sluggish development of the selling side of the electricity business. "Value of service" is an admissible factor in any business that is not at the same time an absolute necessity to the public and a monopoly to the providers. Shop-window lighting is only poor business because we are obliged to sell electricity within a certain figure per unit, irrespective of its value to the user. Certain shops would pay double the present rates rather than give up electric lighting. We used to offer low prices for basement lighting in order to acquire a day load; now we find that basement rents have increased immensely because electric lighting and ventilating have made the basements almost as useful as naturally lighted rooms. A basement with a rental of £50 per annum can be well lighted and ventilated for £5 to £7 per annum. Without the ability to use electric light its rental might drop to one-half or less. Electricity converts a cellar into a room.

In reply to Mr. Couzens, the actual form and method of operating a supply tariff is probably of less importance than the energy and initiative of those in charge of it. So far as the domestic business is concerned, neither a low average rate nor a perfectly balanced tariff alone can bring success; it must be supported by help for the consumer in regard to the more expensive apparatus and its upkeep.

In reply to Mr. Tuckett, there has always been a marked difference between the competitive value of the return from a unit of electricity as used for

light and heat. This is accentuated by improvements in lamps, and entails increasing differences between the price of energy for lighting and for heating. These differences are not too easy to explain to consumers, and could disappear under a sound form of subscription tariff.

With regard to Mr. Purse's remarks, the full advantage of a single-meter tariff in regard to cost of wiring can only be enjoyed in the case of buildings wired with the knowledge that such a tariff will be available; it is then possible to make very substantial savings. There appear to be two schools of thought with regard to cooker practice: (1) To produce an infallible cooker, hand it to the consumer, and leave both the utensil and the customer alone. (2) To produce a more or less fallible cooker designed for quick replacement and repair with standard parts, and to keep in regular touch with the user in regard to maintenance and instruction in use. I believe we can only reach the first by way of the second; success to-day in electric cookery depends on the establishment of organizations to care for the apparatus and lead the users to understand and appreciate what is really a new method in the home.

In reply to Mr. Cowan, if it be admitted that the increment cost of any moderate increase in the number of connections (marginal consumers) is small, one must remember that each new connection is bringing nearer the day when a further unit of machinery, etc., will need to be installed and in its turn made remunerative by the gradual building up of still more connections. A transaction which though not yet a source of loss might become one if multiplied beyond a particular degree, is in the nature of "dumping" rather than "selling."

Mr. Minton referred to inaccurate meters. Such inaccuracies on large power supplies are often met by an arrangement of three meters and an agreement to accept the average readings of the two meters whose readings are most nearly alike.

I agree with Mr. Rye that, much as a multi-part tariff can help to build up a domestic load, it yet requires to be supplemented by every possible means of introducing to the consumer the advantages of general electrification. It is by using electricity for purposes other than lighting that we realize the simplicity and economy of this method of charging. It was noticeable in many instances that when circumstances led suppliers to increase their two-part tariffs, often by doubling both the fixed and running charges, the system tended to fail on purely lighting businesses, whilst the consumers who used electricity for a number of different purposes were much less dissatisfied and still obtained advantages from this method of charging.

In reply to Mr. Gillott, I have suggested for consideration that a multi-part tariff should provide for increasing the fixed charge in relation to large increases in connected load (i.e. potential increase in demand), because I feel that there is a weakness in basing it on lighting only; it may lead to the running rate being made too high, or to the tariff not allowing sufficient for liberal expenditure on distribution works.

With reference to Mr. Cooper's remarks, there is an evident reluctance on the part of suppliers to quote special rates for so-called 100 per cent load-factor apparatus. The composite tariff takes care of such load automatically, even if no further concession is contemplated for "restricted hour" use.

In reply to Mr. Dick, I look to a basis for the fixed charges broader than that for lighting only, to enable copper to be laid for the growing domestic load; and to future development of heat-storage apparatus to obtain the maximum duty from that amount of copper.

The contributions to the discussion by Messrs. Madgen, Elvy, Sayers, Woodhouse, Phillips, Ritter, Bentham, and Lieut.-Col. Vignoles are in the nature of valuable additions to the matter and arguments contained in the paper and call for no reply by the author.

Mr. Fedden has put on record arguments which he does not advocate and which, moreover, have probably caused him a considerable amount of work; they are of interest as summing up a minority opposition, which arises from time to time in different districts, to the recognized basis of charging. Perhaps in time to come we may sell electricity for all purposes at a single flat rate; at present it is necessary to consider only what would happen if such a principle were suddenly introduced into a large mixed industrial and residential area. The increase in the cost of power and the decrease in the charge for lighting would probably soon result in destroying most of the industrial load and leaving the public with its lighting at a rate which, though prohibitively high, could not save the undertaking from bankruptcy.

These theories when honestly held arise from failure to appreciate the economics of the electric supply business. The idea of treating all consumers alike as a matter of equity seems to make it difficult for some to recognize that in buying electricity (i.e. sharing the upkeep cost of the undertaking) it is only by highly differentiated rates and charges that the burden can be equitably adjusted to each consumer in accordance with the expense to which his particular service commits the supplier.