The Use of Electricity in Agriculture

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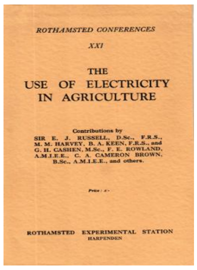

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THE
USE OF ELECTRICITY
IN AGRICULTURE

Contributions by
SIR E. J. RUSSELL, D.Sc., F.R.S., M. M. HARVEY, B. A. KEEN, F.R.S., and G. H. CASHEN, M.Sc., F. E. ROWLAND, A.M.I.E.E., C. A. CAMERON BROWN, B.Sc., A.M.I.E.E., and others.

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THE USE OF ELECTRICITY IN AGRICULTURE

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SIR BERNARD E. GREENWELL, Bt. M.B.E.

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G. H. CASHEN, M.Sc. and B. A. KEEN, F.R.S.

FOREWORD

By Sir E. John Russell,
Director of the Rothamsted Experimental Station.

The interest of Rothamsted in electrification goes back to 1930, when Mr. Borlase Matthews, one of the pioneers of the movement, prepared a scheme for performing all operations about the farm buildings by electrical power. For various reasons, however, it was not then possible to do anything and the matter was in abeyance till early 1932 when Sir Hugo (now Lord) Hirst generously provided the sum of £500 for equipment and arranged for the services of Mr. F. E. Rowland, the agricultural expert of the General Electric Company in making the plans. Another £500 needed for wiring and other works was provided with the consent of Miss Müller out of a legacy left by her mother, widow of the late Dr. Hugo Müller, formerly Treasurer of Rothamsted. Although the farm buildings lay more than a mile away from the nearest source of supply the North Metropolitan Electric Power Supply Co. entered wholeheartedly into the scheme and laid the cables free of cost so that the Institution should not be saddled with a burden of high charges. The equipment charges were of course greatly in excess of what would be needed on an ordinary commercial farm because it was intended from the outset that both the experimental, and the ordinary commercial work about the farm buildings should be done with electricity, and further that comparisons should be made at each stage with the tractor or other oil engine so as to give farmers the data on which they might determine whether it was or was not worth their while to install electricity. When the installation was complete the Royal Agricultural Society made a grant out of its Research Fund to enable records to be taken. This work has continued over a period of three years in consultation with the Oxford Institute of Research in Agricultural Engineering and with Mr. Rowland ; the actual recording has been in charge of Mr. G. H. Cashen, assisted by Mr. E. C. Wallis.

Some of the data are presented in the paper by Mr. Cashen and Dr. Keen. They show that with a 20 h.p. motor or a 10-20 h.p. International tractor, each running at approximately half-load, 4 units of electricity or 5½ pints of paraffin were consumed in threshing about one ton of grain : the operation taking half-an-hour, so that the hourly consumption was double these figures. Preliminary experiments on the grinding of barley, using a 5 h.p. electric motor or a 6 h.p. Bamford oil engine, each at an output of 5 h.p., showed, for the same grinding rate and fineness of grinding,

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that 4.6 units of electricty per hour were equivalent to 2.3 pints of diesel oil per hour.

At the price we were paying (1d. per unit + 0.42d. representing the fixed charge spread over all the units consumed during the year) electricity comes out actually a little dearer than paraffin, and dearer still than diesel oil, but when account is taken of the overhead costs the balance is changed : electricity is cheaper than the paraffin tractor but a little dearer than the diesel oil engine.

The convenience of electricity, however, goes far beyond this and we have made no attempt to estimate the value of the better lighting as compared with the old days of lanterns, and of the enormous advantage of being able to start and finish a job simply by pressing a button.

During the past few years great experience of electricity has been accumulated both on the farm and on the engineering side, so that the farmer now has a wide range of motors and other appliances from which to select. In the following pages the various possibilities of the use of electricity and of types of appliance are described, but no particular article is recommended. It is easy for a farmer to get in touch with reliable sources of supply but, as Mr. Cameron Brown shows, good workmanship is essential. A long life can be safely assumed for good modern motors and good wiring installations, and the overheads are proportionately low ; but for inferior appliances and bad wiring the life is shorter and the overheads higher.

Farmers who have never used electricity will find Mr. Harvey's paper both interesting and helpful in showing how to take the first steps to secure the supply and how best to utilise the current when they have got it. The number of uses is considerable and although hitherto more current has in general been used for light than for power, except on dairy farms, the scope is steadily widening and with more experience, fresh applications will steadily be found. Mr. F. E. Rowland describes suitable types of appliances for the different purposes.

Not very long ago it used to be said that a farmer must be a bit of a chemist, a bacteriologist, a veterinarian, a meteorologist, a mechanic and a business man : if in addition he had to become an electrician his life would indeed be hard. But this is quite unnecessary. Modern motors are so good and their vital parts so well enclosed that nothing should go wrong with them. It is, however, well to have the installation periodically tested as leaks may occur and there are certain possibilities of danger in faulty wiring. This testing can be done by the Supply Company.

In the following pages we are concerned only with the immediately practical applications of electricity. Nothing has been said about such matters as electrical ploughing and cultivation, or electrical discharges over crops (shown by Prof. V. H. Blackman and his assistants to have no practical value) or the various horticultural possibilities such as soil heating and forcing of plants by artificial light. For the present we are concerned with the farm only, yet as the papers and discussions show the possibilities are distinctly impressive.

The Chairman, Sir Bernard Greenwell, said in his opening remarks that the grid system could provide electricity at a more uniform and cheaper rate than the numerous small generating stations that it was now replacing, but with this high tension distribution separate transformers were necessary for each group of small consumers and for isolated farms. Capital expenditure on such construction and for carrying the low tension supply to the consumer had to be met. The simplest and fairest way was for the consumer to bear his share in the form of a standing charge and to pay at a low rate per unit for electricity consumed rather than to merge these two distinct items into one by charging a higher rate per unit. Fortunately the cost of transformers was becoming cheaper. In country districts encouraging results had been obtained with the use of a modified mole-plough for laying underground cables at a cheap cost, and those people who dislike the appearance of pylons with their overhead cables could take hope for the future.

"ELECTRIC POWER—HOW TO OBTAIN IT AND HOW BEST TO USE IT."

M. M. HARVEY

(The Shropshire, Worcestershire and Staffordshire Electric Power Company)

Summary of Contents.

The general purpose of this paper is to indicate how farmers who are within reach of a public electricity supply may obtain the greatest benefits for their outlay of capital, and the general trend of electric farming development as related to the various types of farms.

The sections dealing with wiring and motors have not been dealt with at great length, owing to the fact that several other authorities are dealing with these specialised applications at this conference.

I have mentioned tariffs and indicated the reasons for the various charges to consumers, as there is often some confusion in the minds of consumers for the reasons for guarantees, minimum charges, two-part tariffs, etc.

The types of farms using electricity are tabulated with some specialised applications, and in section three, the various appliances are discussed at greater length.

The other sections deal with private plants; the verdict of farmers already using electricity; some details of actual installations; tables of running costs and other data collected from various sources and authorities.

This paper only deals with practical applications and those which have been successfully adopted in one type or another of farming, no " futuristic " applications are discussed.

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INTRODUCTION

LOOKING back over the last six years, the points which strike one who is connected with the electrical supply industry, is the changed attitude of the agriculturist and rural dweller to the use of electricity in the house and on the farm. To one who is connected with a group of companies supplying current to an intensely rural and scattered area with a very low population ratio, this changed attitude is very welcome. You may ask what change is this? It may be summed up very concisely: a decade ago the farmer said to us when we were obtaining wayleaves, " keep those ugly lines as far away from my farm as possible, I don't want the current it is too dear, and I don't know anything about it." We had the task of developing this rural area, as far as economically possible, and the greatest difficulty we had was to arouse interest of the rural dweller. Now, however, as the result of articles in the press, the agricultural trade papers, exhibitions at village halls and agricultural shows, and the universities and colleges, the farmer has become quite electrically minded, and comes to us and asks for a supply and for the lines to be brought near his farm, instead of the other way round.

Rural electricity development is discussed at every rural and parish council meeting and at national farmers union meetings, and, if the remarks are not always complimentary to the electrical supply industry, these remarks at least show that interest is aroused and rural dwellers are taking an interest in electricity, even if they do not perhaps realise the difficulties of supplying a thinly populated area, with a relatively small return on outlay.

The points discussed in this paper are rather in the shape of a review of well-known and tried applications of electricity such as are used on the farms of the south and west midlands and part of south Wales, the immediate area supplied by the company to which I belong.

Some of the points are controversial perhaps, but this is all the better from the point of view of a discussion.

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1. RURAL DISTRIBUTION OF ELECTRICITY

Before and immediately after the Great War, electricity supply was restricted to urban areas, and the immediate area around the large towns. Electricity was also available in some small country towns, where it was generated by small power units at low pressure, very little rural development was to be observed.

In 1919, the Electricity Acts provided for the setting up of the Electricity Commissioners and the transfer of the powers of the Board of Trade to the Ministry of Transport. This was for the promotion of schemes for re-organising supplies of electricity, and special orders with joint authorities.

The Act of 1926 organised, on a national basis, the country at large as a whole system, with schemes for various urban and small areas. Provision was made for interconnecting generating stations, and for the shutting down of small inefficient generating stations, also for the organising of a standard voltage or pressure of supply, and a frequency of 50 cycles. This means that there is now more or less a standard electricity supply available which cheapens production of manufactured electrical goods and obviates the nuisance of an electric iron bought in one area being useless if used in another area. The grid lines are therefore actually interlinking super station to super station and are not for distribution purposes as so many people imagine. The Act of 1926 put the generation of electricity on a national basis, the distribution to consumers being left to local authorities and companies. This corresponds to the organised selling and Marketing Boards set up for agricultural produce.

In areas where no power station is situated, power companies and authorities may purchase current from the grid for sale to their consumers.

These grid lines on large steel towers work at a pressure of 132,000 volts with some secondary lines at 66,000 volts. Power authorities also have their distribution high pressure mains of 66,000, 33,000, and 11,000 volts ; when these reach a village, hamlet or town these pressures are transformed to a working pressure of 400 and 230 volts.

Farms within easy reach of the low tension mains are in most cases connected up, and more and more in the future the question of supply to farms from high tension lines, or long lengths of low tension mains will be the leading factor of rural electrification.

Wayleaves have been necessary between supply authorities and landlords and tenants, to enable these lines to cross land, and it

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says much for the rural dweller that generally an amicable arrangement has been arrived at for the erection of these towers and poles, so that there is the minimum of interference with agriculture. Farmers should understand however, that every deviation from a straight line, means extra cost in line construction, extra strong supports, stay wires, etc., which put up the cost of construction and tend to limit development of an area on the score of capital cost.

Farmers naturally say, " How can I obtain a supply of electricity as I am not near to a village supply with low pressure mains ? "

It is quite uneconomical to tap high pressure lines of 66,000 and 33,000 volts for isolated farms, but most authorities will tap 11,000 volt lines on some basis of charge.

This tapping of lines includes as a capital cost : switchgear, transformers, isolated sub-stations to hold this gear, and lastly the low pressure lines to the farm, and the authority has to cover itself on loans for capital expenditure, depreciation and maintenance of equipment and transformer losses which run on continuously for 24 hours per day, year in and year out. This means that each tapping has to cover in its charges a sum equal to this amount, and, if included as a flat rate per unit, the cost would be too high per unit to make the use of electricity economical for some purposes. Therefore, there has been developed a system of tariffs in some areas whereby the authorities generally bear part of the cost of the transformer and H.T. switchgear and transformer losses and maintenance, and the farmer pays for his low pressure lines to be erected by the Authority, or erects them himself to a standard construction.

The price per unit is then fixed at approximately the same price as if the farm was on a low pressure village system, plus a standing charge or guarantee to cover the extra cost of this equipment to give electric service to this isolated consumer. In fact, we say to the consumer, " We will supply you with current at approximately the same basic price per unit as if you were in a village, but it has cost us a certain sum of extra money over a village scheme to make this service available to you, and we therefore ask you as a business man, to guarantee a sum per annum as a contribution towards the cost of this service, based on a percentage of the total capital cost involved, or guarantee that you will use a minimum amount of current per year to meet these charges." Most farmers, as business men, immediately see the point, especially as most guarantees include a number of units of electricity in this amount. These guarantees may be fixed as a percentage of capital cost, or based on the demand likely to be made by the farmer, or on the size of his buildings and number of rooms in his house. It is not often realised that the percentage costs of giving electric service to a rural area are in the region of 75 per cent. for distribution mains, and are totally different to town supplies. Also, an authority has to raise loans from investors to erect these schemes, and the investors naturally require a return on their money. If this return is not available investors will not lend money and the development automatically ceases.

This system of a guarantee and a lower rate per unit than a flat rate may be explained in this way. In any business or farm, there are certain overhead charges, such as rent, rates, living expenses and labour which go on continuously whether large or small quantities of produce are produced. Now, if a farm is producing a certain quantity of product per year the price obtained at a flat rate per gallon or ton has to cover these charges, whether all or any of the product is sold, and if a smaller quantity is sold the revenue obtained must be larger to cover these overhead charges or a loss is incurred. It is therefore, better to sell all products if possible, even if a lower rate is obtained, as long as the overhead costs are covered. Thus, one might suppose a buyer to say to the farmer, " I will guarantee to take your products, but instead of paying you at the flat rate per gallon or ton, I will contribute a certain sum per annum according to the quantity you produce or sell me, to cover your overhead costs. These will then be covered, and you will not be at a loss. You can then let me have your produce at a lower figure than the flat rate, or just above the cost of production. You will then be in a better position than if you sold in the flat rate market, as you are fully covered for overheads and can afford to sell at a lower figure per ton or gallon for your produce as you have a guaranteed market." This is really the basic principle of all marketing schemes.

A simple explanation of the extra cost of rural distribution over town distribution is as follows : Suppose a farmer retails 100 gallons of milk daily from vans in a town or a few streets, his customers are close together and a few vans can deal with this retailing, and the delivery costs per gallon are low. Now suppose that a farmer had to retail to the same number of customers the same number of gallons over the whole of his county, his distribution costs would immediately rise many times per gallon over his town delivery costs, and he would have to obtain a higher price per gallon to cover this. This explains why the rural dweller has to pay a slightly higher price per unit than the town dweller. Some farmers may ask, " Why am I charged at a higher standing charge for a large transformer than a small one ? You are penalising me if I want to occasionally make a larger demand on your system." The explanation is as follows : Suppose a purchaser was willing to take 50 gallons of milk daily as a maximum from you. You could budget for sufficient cows to give this daily supply, and as long as he did not exceed this quantity he would be a satisfactory consumer, but supposing he said " I want 50 gallons of milk daily, but perhaps for one day only in the year I may require 200 gallons from you." You would be in an awkward position of having to keep a larger herd just to supply this one day's demand, and you would be justified in coming to some arrangement with this customer to pay you extra for this availability of supply of milk, as your overhead charges would have to cover these extra cows for one day's supply only of their product. This is the same in effect as our maximum demand charges; it pays any producer better to have a constant demand at a lower maximum output than an erratic spare-time demand at a higher level.

Isolated farms and estates should view the capital expenditure on service lines in the same way as they would capital invested in private plant, looking at it from the point of view that the farmer is freed from all generating worries, plant upkeep, and has generally a greater horse-power available for farming and larger domestic appliances. Most companies fix guarantees within reach of the annual consumption when electricity is used in a reasonable way, and, although guarantees may seem hard at first, many farmers have found that they have an incentive to use current to the best advantage, and often find the labour saved in pumping and dairy and poultry appliances goes a long way to offset the guarantee. The Chester area have found guarantees to work quite satisfactorily and numerous testimonials, with names and addresses of farmers who gave them, will be found in E.D.A. Booklet No. 1179, read at the R.A.S.E. Show at Derby in 1933, by Mr. S. E. Britton (*Five Years' Progress in the Electrification of Agriculture Round Chester*).

Many of our farmers are on this guarantee system, and they see that they use up to the amount they have to pay for. Some details of the number of units used for various operations on an average farm will be of interest. I have also indicated the unit consumption per ton or cwt. for various machines. These will be found in the appendix.

Farmers desirous of obtaining a supply of electricity, if within reach of high or low-pressure lines, should apply to their local electric supply office, where they will have to obtain an application form, and fill up the various sections relating to the amount of load to be connected to the mains, and to the tariff to be adopted. The supply authority will then advise him of the length of main to his premises, the contribution or guarantee required, and when a supply can be made available. The consumer should have his premises wired by an established supply company's wiring department or skilled electric contractor. A good installation is worth the little extra first cost; it is good to remember the old slogan, "Service and convenience are remembered after first cost is forgotten."

Farmers will ask, "How much shall I use per year?" This will obviously depend upon the type of farm and the installation. The average consumption of various types of farms on the S. W. & S. power company's mains suggest that the highest consumptions are from dairy and poultry farms, which average 2,000 to 7,000 units per year—one large hatchery consumes 17,000 units per year—some mixed farms with hops average 2,000 to 5,000 units per year.

Two large dairy farms reach over 9,000 units per year. The average consumption for 29 farms reaches over 4,000 units per year.

Regarding tariffs, the supply authorities have various methods of collecting the first part of the two-part tariff, some being on the acreage of the farm, some on the connected load of farm motors, some on the lighting installation, others on the number of rooms, or the area of the house, plus a standing charge on the floor area of the main farm buildings. This may seem very confusing to the consumer, but in practice the cost of current to the user works out practically the same whichever method is adopted to collect or assess the standing charge. All these systems have a small unit charge, and the assessment for the first charge only increases the unit cost for the whole premises by a very small fraction of a penny per unit if adequate use is made of electricity.

2. TYPES OF FARMS

Obviously the greater number of farms using electricity are situated near the larger towns or villages, and are of the intensive or semi-intensive type, such as poultry and dairy farms, whose productive methods and marketing more closely approach the factory system, and machinery is used to a greater degree than on the prairie types of farms, as these factory type of farms produce perishable foodstuffs, and constant delivery service is everything.

Taking the various types of farms, one is struck by the fact that the geographical position and methods of agriculture and even marketing schemes and political development determine the consumption of electricity, for instance, the large poultry farms and hatcheries of the North and the Midlands ; the better prospects of the hop farmers during the last few years, and the dairy farms near Birmingham, and then turn to the sheep farms of Brecon and Radnor, where very little machinery is used, nor can it ever be owing to the geographical position and the type of farming.

The various types of farms and their installations are outlined below.

Poultry Farms

There has been a tendency during the last few years to go "back to the land," or free-range rearing of chicks and housing of laying stock where the land has been available. Electricity is used for : incubation in small and mammoth machines ; rearing, where the semi-intensive or intensive method is used, and even where "limited" free range is used we have fitted up portable foster-mothers with heaters and trailing cable ; electric lighting for winter egg production in large and medium size laying houses ; warming drinking water ; egg candling ; and on the larger farms mash mixers ; hot water for mashes ; egg grading ; poultry plucking on table bird farms ; water pumping ; egg washing and drying, and other uses ; and of later times lighting of hen laying batteries.

Dairy Farms

Electricity on dairy farms is used for water-pumping ; refrigeration where a bottled trade is done ; milking machines, both for pipe line and combine or recorder types of milking machines fixed in bales near the buildings ; cow clipping ; food production and mixing ; bottle washing ; hot water ; separating and churning (though this application is not now so much used) ; sterilizing utensils ; steam production ; general lighting of milking sheds and buildings ; and on the larger retail distribution farms bottle-filling and capping machinery ; motor agitators for pasteurizers ; curd mills ; fans, etc. ; and for electric vans for town delivery from near-by farms.

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Mixed Farms

This term is very elastic, as in Worcestershire and Herefordshire we have perhaps not specialized so much on one type of farming as in some other counties, and I often say we have not felt the Agricultural depression so much, owing to the farmers having several "strings to their bow" in cattle production, pig production, milk, poultry, fruit, corn, hops, and sometimes market gardening. I know one large farm in the Vale of Evesham where practically every section is carried on. The electrical equipment of these farms varies more than any other type, as the bulk of the power farming is done on the land and not in buildings such as on the dairy and poultry farms. The applications will partake of a little of each type, such as a certain amount of the dairy and poultry machinery, food production and corn grinding, threshing, pumping, motor-driven fans for hop kilns, and lately air compressors for fuel-oil hop-drying plant; and of course, general lighting. In the West Midlands some of our large fruit and mixed farms have installed small canning plants, with motors for bottle-washers, fruit graders, canning machines, etc. Taken as a rule, I find that although the connected motor load is often larger for these mixed farms than for the other types, the consumption per horse-power is lower owing to the fact that the uses of the machines are more seasonal.

Large Arable Farms

Electricity on these large prairie types of farms is generally confined to the farm-house and general lighting in the farm buildings —water-pumping, motors for driving barn machinery, threshers, grinders, mixers, hoists and grain-dryers, etc. The electrical equipment for these large arable farms does not tend to be so great as on the poultry, dairy and mixed farms, as the power is most used on field operations, and the indoor work forms only a small part of these mechanized farms. Of course, if the farmer launches into any other system of agriculture his uses will increase with the acquisition of dairy and other equipment. The unit consumption, per acre, of electricity is generally at its lowest on these types of prairie farms.

Hop Farms

Except in a very few cases, these farms are not specialized hop-growing farms, but carry on a certain amount of other types of mixed farming, chiefly corn production and cattle feeding. The uses of electricity in the hop kilns are motors for driving ventilating fans of the exhaust and pusher types, motors for hop pocket hoists and bagging presses, small motors for air compressors for fuel oil fired kilns, and electrical thermostats for the control of the flow of oil to burners. Lighting of hop kilns, bagging and cooling floors is always adopted where a supply of current is available. The safety of electricity for lighting is most helpful in combating the

C

fire risk in hop-pickers' quarters. Some of our Midland growers are contemplating the use of their hop kilns for grass drying in the spring and summer, and already some few have done this. One or two in the Vale of Evesham have dried herbs for the market gardeners in their kilns.

The yearly consumption of hop farms is reasonably good, but as it is a highly seasonal operation, the bulk of the units are over a four to six weeks' period in September.

The use of hop kilns for grass or crop drying will assist the farmer to keep down the heavy proportion of capital costings on kilns and equipment only used one month in the year, by spreading this over a greater period.

New Developments

As already mentioned, the drying of short grass in the spring and summer of the year, for producing a food of high protein value, is attracting a good deal of attention. During **1936** there should be quite a number of these plants working in the West Midlands. This particular type is marketed by one of our leading chemical and fertiliser firms, and it necessitates a special drying plant, using coke for generating producer gas for heat, or fuel oil may be used. A large electric motor is used for the fan.

Some of our farmers are contemplating adapting their hop kilns for this dryer.

Some of the fuel-oil heater firms also make outfits of large and small capacity—in one make the agitator tray is fitted to the kiln heater as an extension.

The use of the combine harvester has brought grain dryers into prominence and electric motors are used for the fans of these machines.

Market Gardening and Horticulture

This type of specialized agriculture does not usually come within the scope of the average farm, although some of our Worcestershire farmers have large field market gardening systems.

In the field type of gardening electricity has little outlet except for pumping for irrigation.

One large Worcestershire farmer during the last three summers has fixed up a pipe system along the headlands of his fields with convenient taps to which he attaches rubber pipes connected to long lengths of galvanized piping drilled every two feet or so, the pipes being mounted on low trestles across his strawberry and soft fruit plantations. This artificial rain has saved his crops during the drought seasons and amply repaid him for his outlay. The sets of pipes are periodically moved up and down the field. Water is obtained from the river.

Horticulture and Glass House Work

This does not come strictly within the scope of the farmer. We have glass-house owners using electricity for ventilating fans, pumping, lighting, and in one or two instances electric heat for frost protection in low temperature nursery houses.

I feel that at present one has to go very carefully into the economies of greenhouse heating by electricity on a commercial scale before advising its use for the higher temperatures required in cucumber and tomato houses.

A number of horticulturists are using soil-heating cable in a small way for propagating frames and where bottom heat is required.

There are several new electrical applications in horticulture, such as neon lighting, which are in the experimental stage as far as England is concerned.

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3. ELECTRICAL INSTALLATIONS ON FARMS FOR DOMESTIC AND FARM PURPOSES

The House

The lady of the farm generally insists upon an adequate installation of electricity in the house, and apart from the convenience and greater illumination power of electricity, the saving in labour should not be overlooked.

One farmer in Herefordshire, who has used electricity for twelve years, has told me that since installing a cooker, vacuum cleaner, electric washing machine and iron, his wife can manage without a maid at £28 per year wages, her food and room. The electricity bill for his whole farm did not come to this amount in a year.

Electrical Wiring

Any of the well-known systems—lead-covered, tough rubber or conduit—may be used in the house. The first two are generally used in surface systems, and the latter is sunk work. An adequate number of points for lighting, heating and wireless should be put in when the work is installed, to save disappointment at a later date. Two-way switching should be used on all stairs and long corridors, bedrooms and large rooms with several doors.

Modern lighting fittings obviate the glare of exposed lamps. The lamps themselves should be of the new coiled coil pearl type.

Power outlets for the use of vacuum cleaners, fires and other domestic aids should be installed in every room.

Hot water may be cheaply supplied for the bathroom and kitchen, either from individual lagged heaters or from elements fitted into the lagged cylinder of airing cupboards working in conjunction with the back boiler of the grate. All these various types of water heaters are thermostatically controlled, giving the utmost efficiency of operation.

The kitchen is the workshop of the house, and there an electric cooker gives the most hygienic and unparalleled results : the oven is airtight and no fumes are given off ; while there is little or no shrinkage of the meat, owing to the efficient lagging and airtightness the heat is retained for hours after the oven is switched off, and puddings, etc., may be cooked after the heat is switched off. The cost of cooking averages out at about one unit per person per day.

An electric refrigerator keeps the food fresh and saves wastage ; and electric irons, kettles, washing machines, wash-boilers, etc., help the housewife in her work.

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It is noticeable on the " family-run farms " of South Wales, that often the wife and daughters are doing outside barn work and stock feeding while the electric cooker prepared the midday meal without attention.

Many ladies now use electric hair-dryers and curling-tongs, and ceiling type reflector fires are a boon in the bathroom.

Electricity in the home cuts out the drudgery of work and gives large-town amenities to the rural dweller.

Many farmers when seeing the usefulness of electricity in the home have adopted it on the farm.

Finally, go to reputable electrical engineers for your installation.

ELECTRICITY ON THE FARM

Wiring Systems

As another speaker is dealing with the details of farm wiring systems, I will only briefly touch on them.

The usual systems for farm work are somewhat similar to those in the house. The systems may be vulcanized indiarubber cable run on cleats, and where liable to damage enclosed in galvanized piping —tough rubber-sheathed cable with all insulated fittings. I am partial to this system, or a galvanized screwed piping system, which is a very fine job, though more expensive in first cost. I am not in favour of lead-covered cable in farm buildings.

Fuse-boxes protect the circuits, and detachable ceiling roses are useful for cleaning lamps and shades.

For carrying mains between buildings, simple iron brackets or wall spikes fixed on the walls with small shackle or reel insulators may be used with an insulated cable of the appropriate class. These mains should be erected high enough to clear any harvesting waggons.

Power Wiring

This is usually carried out in steel conduit with ironclad switch-gear and ironclad switch plugs for portable motors. Generally a few points for portable motors scattered round the buildings will suffice for most jobs.

With this 400-volt power wiring, attention should be paid to earthing ; and if doubtful of the earth, use should be made of the small earth leakage trips now on the market.

Farm Lighting

Lighting is the first and most useful application in the farm buildings and yards, and its use is encouraged by many authorities, including the N.F.U. insurance department. A man working with a hurricane lantern at night is a " one-armed man."

Adequate lighting in dairies and milking sheds is a profitable investment.

For barn lighting, a light high up over the centre waggon space will suffice, as the sides are usually filled up with hay and straw.

For stables, lights on the centre line will be adequate, the number depending on the size of the stable. Do not forget a plug for the horse-clipper when wiring the stable.

In food-preparing rooms, I recommend placing the lamps near or over the machines, clear of all shafting.

In the milking sheds, the position depends on the layout of the cow standings, and whether one or more lines of stalls are in the sheds. In some cases of low-roofed single-line stall sheds, the beams may interfere with suspended roof lights ; in these I recommend angle lights on the wall at the rear of the cows, pointing down to the cows' hind quarters. In the case of two-line sheds, these generally have a central gangway and two gutterways, the cows' heads being against the feeding gangways on the side walls. If two lines of lamps over the line of the cows' udders are not used, one centre line over the gangway may be installed clear of any manure carrier.

For yard lighting, lamps may be fixed in corner wall brackets to light two ways, or suspended on a catenary system from rough poles over roadways. Watertight fittings must be used, and two-way switching is an advantage on long lines of sheds.

Plugs mounted on walls for hand lamps are useful in piggeries and cow sheds during illness of animals, and appreciated by the "vet."

A portable floodlight is often useful round buildings and yards for night work. One of our farmers in South Wales uses a 1,000-watt floodlight on a pole in a small paddock near his house during the lambing season, so that his shepherd may attend to his ewes. This has saved him many ewes and lambs.

In the modern pig house, lights over the feeding gangways assist at feeding-time.

In the dairy itself, totally enclosed fittings are the most hygienic and the standard of illumination is higher than that of the outside barns and sheds, plenty of light being required near the milk-cooler and weighing platforms.

The washing-up and sterilizing rooms should be fitted with water-tight fittings and switches because of the prevalent steam—bulkhead type fittings are useful here.

On poultry farms the lights in the laying houses should be placed as high as possible to light the floor, food hoppers and perches ; 40-watt lamps ten to twelve feet apart are usually fitted. In brooder houses lamps centrally placed over the runs are adequate ; some farmers use a dimmer for providing a night light for extra feeding-time for the chicks ; this is often done on table bird farms. In houses for the laying batteries for adult birds, a good light is necessary ; these are generally placed in the gangways.

Generally, central lighting is used in incubator rooms with plug outlets for inspection lamps, egg-testing and candling. A desk bracket type of daylight lamp of about 250 watts is used over the benches for chick sexing, for which a good light is necessary.

General lighting suffices for hop kilns with plugs for hand lamps for use in the kilns, and often an outside light over the loading floor for night work.

Pumping on Farms

The electric pump is usually the first appliance the farmer installs after lighting. For shallow wells there are many types of small centrifugal or piston plunger pumps; these are either direct-coupled or rubber belt driven from motors of ¼ h.p. to 1 h.p., mounted on the pump castings; these small pumps stand up to an amazing amount of work. Practically all these pumps are self-priming.

Pumps may also be obtained to pump liquid manure, and gritty liquids, without damage to the rotors. These standard types of small pumps are for shallow wells and suctions up to 27 feet.

For deep well pumping one may use a motor driving a well head gear with rods down the well, or one of the deep well devices such as the injector system, with two pipes down the well; part of the water pumped up is forced down again to bring up water from a greater depth. There is also the totally submerged electric pump for deep wells, which is becoming very popular; this is very simple to install, and is watertight.

A useful type of pump is the pressure tank automatic type. A quantity of water is stored under air pressure in a cylinder; this system avoids large overhead storage tanks, and is useful for small water schemes for groups of cottages. An automatic switch stops and starts the pump according to the quantity of water in the tank.

Electric pumps using storage tanks may be controlled by a float switch mounted in the tank, this again automatically controls the pumping. This automatic control is the great feature of electric pumps.

Small pumping outfits may be mounted on four-wheel trollies for headland irrigation and spraying work—the motors being fed with tough rubber cable.

Barn Machinery and Motors

As another speaker is dealing with electric motors, I will only briefly outline various points.

We find on a number of Midland farms that the farming technique is tending to cut out some of the barn machines, such as chaff-cutters, cake-breakers, and sometimes root pulpers. Grinding is now the chief barn application. The average farm grinder takes from 5 to 10 h.p., and is either driven from the shafting feeding other machines or, if used every day, individual drive by rubber "V" belts. Driving by means of "V" belts is being used to a

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greater degree, making it possible to use larger pulley ratios and higher speeds and cheaper motors. These barn machines are driven by stationary motors on beds or by means of portable motors driving shafting.

Chaff-cutting takes about 3-5 h.p.; cake-breaking $1\frac{1}{2}$-2 h.p.; and root pulping about 1-$1\frac{1}{2}$ h.p.

The heavy applications are threshing, ensilage cutting and blowing. Threshing requires from $12\frac{1}{2}$-20 h.p., according to size of drum and baling gear. Ensilage cutters and blowers take 15 h.p. and corn driers about 10 h.p.

Regarding individual drive to each machine, except in the case of pumps, poultry and dairy appliances and a certain amount of specialized applications on hop-drying, grass and corn-drying, we feel that the average barn machinery does not warrant individual drives; one motor driving a length of shafting, generally, gives a farmer all the convenience he requires. Use is often made of a fixed motor for barn machinery and a portable for odd jobs.

The S.W. & S. power company have developed a semi-portable motor, consisting of a standard motor and starter, mounted on wood baulks with quickly detachable rubber wheels, which has proved popular. The flat wood baulks give a flat surface for foundations, obviating the use of "chocks" for the wheels. When the motor is in the barns driving shafting, the farmer may use the wheels and spindle as a low trolley for farm transport; this has proved very useful. Except for outdoor work, the use of special protected motors is not necessary.

Starters should be robust, and in the larger sizes oil-filled—it pays to fit a good starter.

Contrary to what some authorities say, we find that the fixed and unit drive motors are in the smaller sizes, and the larger ones are made portable.

It is now compulsory to fit a switch adjacent to each power plug for portables, if the wiring rules are to be observed.

In villages where only one-phase supply is available, the position is eased by the fact that prices have been reduced for repulsion induction motors, and capacitor motors have been recently introduced. These particular types overcome the difficulty of starting against small loads.

The small motors used on incubators, small pumps, separators, bottle-washers, milk-coolers, clippers and shearers are generally of the single-phase type, and unit drive is the only correct scheme for these types of drives.

Electric motors are less in capital cost per horse power than other sources of power, and farmers appreciate their time-saving qualities, convenience and low running costs.

Dairy Applications

The dairy farm has varied applications—the motors have been dealt with in the previous section. Milking machines are becoming increasingly popular, and many farmers are installing the releaser type with electric drive, where the bale is near the buildings.

The accredited milk scheme has made the farmer machinery-conscious. The tendency in the S.W. & S. Power Company's area has been for the purchase of milking machines, and a very great interest in electric hot water produced by thermal storage heaters or even wash boilers, and in electric sterilizing chests. We have found that current at 1¼d. per unit is not uneconomical when taking into account the labour saved in stoking and ash handling, the capital cost of boiler houses and the longer life of electrical appliances. These sterilizing chests vary in price, a small one being obtainable for £11 10s. 0d. I prefer the type with washing water heating facilities, and it is an advantage to have a means of turning off the steam at the end of the operation. Some of our farmers have used their low-pressure steam-tight chests for blowing through the rubber tubes of the milking machine units ; this is accomplished by fitting a tap to the top of the chest.

The hot summers of the last three years have resulted in the increased demand for milk coolers and cold rooms, especially among producer-retailers and every satisfaction has been expressed in their use.

The milk schemes for schools have aroused interest in electric bottle-washers, of which there are now many makes on the market.

A new type of storage milk-cooler has been marketed, in which the churns of milk are immersed in a water tank cooled by pipe coils in the water.

Cow-clipping has been successfully catered for by small portable clippers, mostly of the hand motor type.

In some districts near residential areas there is a steady demand for cream, and many separators have been converted to electric drive by means of ¼ or ⅓ h.p. motors.

The protection of motors in dairies is generally of the drip-proof type, or in some cases totally enclosed motors are used.

The larger dairy applications have not been dealt with, as a visit to the London dairy show will convince anyone how impossible it would be to carry out these factory type of processes without electricity.

We have very few cheese farms in our area of supply ; the few that exist are using motors for curd cutters, whey pumps, electric hot water, and fans for ventilation and cooling dairies and cheese rooms.

The cleanliness of electricity has made it an indispensable power for the dairy.

Electricity on Poultry Farms

Where available, electricity has been used in increasing amounts during the last few years. There are two noticeable points : the first is the changed system of chick rearing in many farms, the policy

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now being to breed and rear for stamina by getting the chicks out on grass as early as possible. This means that there is not such a great use made of battery brooders and large brooder houses, except for table bird production. We have equipped a number of outdoor foster mothers with heaters and fed them by means of trailing cable, or tappings from an overhead cable system stretched between poles.

The second noticeable change is the general adoption of large mammoth cabinet incubators, generally of the all-electric type, instead of using a number of small incubators. The day-old chick trade has helped to bring this about. In a treatise published in 1935 by The Oxford University Department of Agricultural Engineering Research (author, C. A. Cameron Brown), the running costs of all-electric incubators has been discussed and illuminatory figures given to show the fallacy of the statement that oil-heated cabinets are much cheaper in running costs than the all-electric types.

In rearing appliances, opinions are still divided on the question of luminous or lamp type heaters as against black heat types such as plates or boards. Many of our consumers have arrived at the conclusion that there is no difference in quality of the chicks produced. These brooders are now much more robust and simple than the early types and thermostat control is becoming recognized as a means of economy of current and labour.

In battery brooders preference is generally expressed for the types employing a separate warm compartment and a cooler feeding compartment.

Our poultry farmers and general farmers install electrical rearing appliances as a matter of course as soon as a supply of electricity is available.

Where laying houses of the semi or intensive type are in use, one invariably finds electric lighting installed for extended hour lighting for winter egg production; the morning system or, alternatively, the late lunch system of lighting at 9 p.m. for one hour, seems the most popular in our area. Owing to the seasonal tendency of the egg prices to become dear early in the autumn, we find lighting is often started in September and left off in late January. The lighting cost generally works out at $\frac{3}{4}$-1 unit per bird per period of five months.

The increased interest in table bird production has given rise to increased use of motors for mash mixers, ventilating fans for large fattening houses, poultry plucking machines, in addition to incubators and brooders.

Many farmers who handle eggs in large quantities are now installing egg-washing and egg-grading machines, and trough heaters for water systems are used on farms where adult bird-laying batteries are in use.

Chick sexing would be impossible without the intense light furnished by electricity, daylight lamps being used. A moveable type of bracket or table fitting is the most convenient type to install.

Some of our larger farms have small woodworking plants and machines electrically driven, to undertake repairs to houses and equipment, and many prefer to make their own wood equipment.

Electricity appeals to the small man just as much as to the large man, inasmuch as his labour costs are reduced, and labour is a serious item in the poultry industry today.

Electric Heat on Farms

Apart from the dairy applications of hot water and sterilizing and the poultry heat applications, electric heat may be used in food boilers, warmers, soldering irons, grain sprouters and radiant or tubular heaters for farrowing pens. One farmer in the North of England has successfully used reflector bowl fires screwed to the angle supports of his farrowing pens directing heat down on to the young pigs in the corner of the pen. These fires may be obtained for 8s. 6d. upwards. I am rather in favour of the radiant type of heater for young pigs. This type of heater could, of course, be used for other animals in cases of illness.

Hop Farms

Increasing use is being made of electricity for driving ventilating fans of various types, both for exhaust use in the top of the kiln and for "pusher" type of fans for use with the various heating systems using crude oil or low grade fuel, giving pure hot air through the hop bed. These motors vary from ½ h.p. to 20 h.p., depending on the size and type of the plant. Probably due to the controlled marketing of hops, the hop farmer seems to be more ready to spend money on new equipment, and more use is being made of unit drive for fans, blowers, etc. This outlook is being aided by the makers of drying plant who prefer electric drive, and build compressors and fans incorporating unit electric motor drive. Hop growers advise us that they prefer electric drive if obtainable.

A number of modern kilns have been recently erected in Worcestershire, incorporating thermostat control electrically operating the oil supply to the burners. An electrical hop-bagging press has lately been placed on the market; this incorporates an ammeter reading in lbs. pressure, and the whole outfit is a compact assembly.

In my opinion electric heat for kilns is not yet economical; when it is applied it will have to be fitted to kilns of the multi-tray type or a dryer designed for continuous operation.

As previously mentioned, some of our hop growers have dried short grass in their kilns. One should, however, fit perforated metal floors instead of the hessian mats. As the temperature required for grass is much greater than with hops, we also found that one had to increase the volume of air going through the grass bed, also increase the heat. Analysis proved that the dried sample was quite good in feeding value.

Hop growers use lighting extensively in hop pickers' barracks, where the installation of electricity has cut down the fire risk. Needless to say, the installation should be robust.

Grass Drying

During the last twelve months there has been great interest in our area in grass drying. The size of the motor required for the fan is generally about 25 to 30 h.p. These dryers may also be used for drying corn or other seed crops threshed direct from the field.

In one particular drier the grass is dried in two stages by a current of hot air drawn up through the grass beds—the drying is continuous. The hot air is produced by gas from coke or anthracite burned in a firebrick-lined chamber. The average drying time per load is 25 to 30 minutes and from 4 to 8 tons of wet grass can be handled in 8 hours, giving 21 to 33 cwts. of dried grass. Drying goes on from April to September or October. The costs of electrical fan drives are given below.

The makers state that the electricity consumption will amount to 28,000 units per season, so that these plants will be good consumers of electricity, if somewhat of a seasonal load.

Dried grass, either from the bale or ground into meal, may be fed to most farm animals.

Special Applications of Electricity

Electrical battery vehicles give a simple means of delivery transport for dairy farmers in towns for house-to-house delivery. The use is generally governed by the distance from the farm to the town, although some farmers transport their milk in petrol lorries to a central distributing depot for delivery by electric vehicles. The advantages of an electric vehicle are that there are no fumes or smells, lubrication problems, erratic starting on cold mornings, no danger of frost, good acceleration, no vibration, therefore little wear on the chassis and body, easy to drive. Batteries are charged in the evenings, generally at special rates. The cruising speeds are generally 16 to 25 miles per hour, and the range at 20 miles per hour is about 40 miles per day. The average current used is one unit of charge gives 5 miles' service, therefore about 8 to 9 units per day are necessary for charging. This application should be noted by farmers who reside near towns.

Electric motors are used for driving fruit graders for apples, plums, and even soft fruits ; these are generally of the 1 h.p. size, but may be as low as ½ h.p.

A number of farmers have installed motors of small sizes for operating can-sealing machines in home canning plants.

Although humane killers do not come within the scope of the general farmer, some possess butchers' shops, and the use of an electric stunner should not be overlooked by the country butcher.

There are a number of horticulture applications which give

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evidence of becoming commercially possible, such as neon lighting for prompting plant growth.

In the poultry industry a certain make of incubator fits a time switch controlling motor driven egg-turning gear, and also an animal and bird dryer consisting of cages through which is blown warm air.

In apiculture, centrifugal honey extractors driven by fractional h.p. motors have long been in use.

4. PRIVATE PLANTS *versus* PUBLIC SUPPLY

A farmer often says, "Why should I pay a supply authority £150 or so for giving me a supply when a private plant will generate current for me at a fraction of a penny per unit ?"

There are many points in this question which are not so delightfully simple as they appear at first glance.

First of all, the generation of electricity is a specialist's job, and a farmer has enough to do to look after his own particular industry without trying to run a miniature power station, with all its worry of charging, repairs, purchase of fuel, etc.

Secondly. The first cost and installation of a plant with its batteries is generally a larger charge than the sum asked by a supply authority to give an isolated supply. A battery plant of 50 volts and only ¾ k.w. costs about £100 with erection and fitting, and a 1½ k.w. plant of the fuel oil type would be over £200 fitted.

Admittedly one can get light, and perhaps run a few very small domestic appliances, but one is prohibited from using room-heating, cooking, motors of several horse-power, and often I have been told one has to run the engine while the ladies are using the iron. Therefore, a farmer has a large capital outlay without being able to get as great a use from electricity as if he had taken a public supply.

Thirdly. One hears wonderful figures on running costs, but farmers have told me their plants have cost them in the region of 9d. to 10d. per unit when all legitimate charges have been allowed, such as standing and running charges, depreciation and upkeep, so many plant users do not realise the very low annual plant load factor of their private installations.

A recent paper read before the Institute of Electrical Engineers by J. A. Sumner, Esq., gives some illuminating figures on the cost of small private plants from figures collected from the owners themselves—these vary from 6.1d. to 12d. per unit.

Now if you will look at Volume II of *Farm and Machine—The Report of the Oxford Agricultural Research Institute in Engineering*, you will find an article on electricity tariffs in which is given the average unit cost in a number of supply authorities' areas. For the house the figure of 2.3d. to 2.5d. per units seems a fair average in truly rural areas. For the farms, the truly rural areas work out at the figure of 1.5d. to 1.6d. per unit.

On the total costs for house and farm combined the unit average price is 1.6d. to 1.76d. per unit.

Therefore one can see that it obviously pays to take a public supply where one is at all available.

Many farmers who have changed over to our mains would never think of changing back to their old system.

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5. OPINIONS OF FARMERS USING ELECTRICITY

For detailed testimonials I would refer interested parties to the E.D.A. Booklet No. 1179, *Five Years' Progress in the Electrification of Agriculture round Chester*, by S. E. Britton, Esq. This contains many actual testimonials with names and addresses.

Our own farmers say they would not return to their old methods —a point which many of them stress is that when the men come home from the fields at 4 to 4.30 o'clock on a winter's afternoon, they will push a button to start a motor to do half an hour's barn work, where in the past it was difficult to get them to start up an oil engine or run in and belt up a tractor for that short period. Many farmers have found it does not pay to run in their tractors to do a short time barn job, as by the time the tractor has warmed up it is time to shut it down.

Dairy farmers on our supply, with electric dairy equipment, make a feature of this in their advertisements to customers.

The ex-Chairman of the Herefordshire Poultry Association, who possesses two mammoth cabinet all-electric incubators, considers his costs to be one-third that which he used to pay for running small oil heated machines.

Many poultry farmers rear their own stock for breeding by electric methods, and report the minimum of losses.

Farmers with pumping schemes have been able to fight the drought of the recent dry summers.

Regarding interruptions of supply to poultry farms, we have many cases where supplies have been off for 3 to 9 hours on incubators with no ill effect. One poultry farmer quite voluntarily allowed us to interrupt his high tension line for 10 hours to effect alterations to switch gear. He had an incubator with 4,000 eggs in it, and he was quite happy about it.

A remarkable case of the hardiness of the embryo of the egg is illustrated by a recent incident at a poultry farm in our area. The farmer has three small electric incubators of 150 chick size each ; on the fifth day of setting, he inadvertently switched one off at 5 p.m., he did not discover this until 8 a.m. next morning, a period of 15 hours. The room temperature was 45° F., he left them in the incubator to see what would happen—1 chick started chipping the shell to time, and the bulk of the remainder came out 1½ days late, with a hatch of about 75 per cent.

Another farmer drying hops with two fan motors of 2 and 3 h.p. respectively and another 2 h.p. on the air compressor of his crude

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oil heater, recorded a maximum demand of 2 k.W. only, and used only 41 units for a 22-hour run on his kilns—this included six lights in his kilns as well as the motor load.

Finally I would urge farmers to make use of the electricity supply in as full a manner as possible, as by so doing they will not only be helping themselves to live under brighter and easier conditions, but will also assist many other industries, such as the British coal trade and engineering industries, which prosperity will in turn result in a better demand for the farmers' produce.

6. DETAILS OF ACTUAL INSTALLATIONS

In this section I am giving examples of wiring and consumption costs on three Welsh farms, with acknowledgment to the University College of Wales, Aberstwyth.

Farm No. 1.

This was a 71 acre holding, 4½ acres arable and 66½ acres grass. The main enterprise on the farm was milk production for which 17 dairy cows were kept. About 50 gallons of milk were sold daily but a sufficient number of calves to replenish the herd were reared. The farm buildings were lit with 6 (40 watt) lamps, 5 of which were fitted in the byre. Electric power was used for grinding, kibbling corn, root pulping and chaffing. It was the intention of the farmer to purchase an electrically driven milking machine immediately. The electrical equipment in the 6-roomed house consisted of 6 lighting points, but the only appliance used was an electric iron. The supply had been installed 18 months. Four people usually lived in the house.

Equipment and Installation Costs

	£	s.	d.	£	s.	d.
Farm:						
Wiring for light	5	0	0			
Cost of motor (6 h.p.)	24	0	0			
Installation of motor	3	0	0			
				32	0	0
House:						
Wiring for light	6	0	0			
Cost of iron		15	6			
				6	15	6
Total				£38	15	6

Current Consumption Costs

Rate per unit: Light, 7½d.; Power, 1¼d.

	Light				*Power*				*Total*			
		Cost				*Cost*				*Cost*		
	Units	£	s.	d.	*Units*	£	s.	d.	*Units*	£	s.	d.
January-March	15		9	4½	21		2	7¼	36		12	0
April-June	15		9	4½	6			9	21		10	1½
July-September	17		10	7½	15		1	10¾	32		12	6
October-December ..	38	1	3	9	38		4	9	76	1	8	6
Total	85	2	13	1½	80		10	0	165	3	3	1½

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Farm No. 2.

This was a holding of 100 acres, 2 acres of arable and 98 acres grass. Milk production was the main enterprise; 36 dairy cows were carried, together with a few young stock and a small flock of sheep. There were 16 lights in the farm buildings, 6 of which were in the cowhouse. In the farm-house of 5 rooms there were two outlets, both being in the kitchen. Electric power was used for milking, pumping and refrigerating. It had been installed in 1930. A bailiff, his wife and three small children lived in the house. The minimum charge was £4 for the year.

EQUIPMENT AND INSTALLATION COSTS

	£ s. d.	£ s. d.
Farm:		
Wiring for lights	16 0 0	
Cost of motor (2 h.p.) for milking	10 10 0	
Cost of motor (2 h.p.) for pumping	10 10 0	
Cost of motor (1½ h.p.) for refrigerating	9 0 0	
Installation of 3 motors	7 0 0	
		53 0 0
House:		
Wiring for light		1 15 0
Total		£54 15 0

CURRENT CONSUMPTION COSTS

Rate per unit: Light, 7½d.; Power, 1½d.

	Light				*Power*				*Total*			
		Cost				*Cost*				*Cost*		
	Units	£	s.	d.	*Units*	£	s.	d.	*Units*	£	s.	d.
January-March	191	5	19	4½	172	1	1	6	363	7	0	10½
April-June	38	1	3	9	287	1	15	10½	325	2	19	7½
July-September	30		18	9	260	1	12	6	290	2	11	3
October-December	77	2	8	1½	22		2	9	99	2	10	10½
Total	336	10	10	0	741	4	12	7½	1,077	15	2	7½

Farm No. 3

A 335-acre farm, 40 of which were arable, 260 grass and 35 acres rough grazing. The stocking of the farm was as follows: work horses, 8; other horses, 5; dairy cows, 40; other cattle, 39; breeding sows, 18; other pigs, 4.

The uses of electricity were for lighting, pumping, grinding, chaffing, pulping. The light circuit of the farm consisted of 13 points, whilst in the house there were 16 lamps. Two fires and one iron had been purchased for use in the house and one cooker had been hired. Five persons were resident in the house. The supply had been obtained just over 12 months.

EQUIPMENT AND INSTALLATION COST

	£ s. d.	£ s. d.
Farm:		
Wiring for light	11 1 0	
Cost of ¾ h.p. motor	7 0 0	
Cost of 9 h.p. motor	20 0 0	
Cost of installation of motors	4 6 0	
		42 7 0

House:

Wiring of light	13 12 0	
Cost of heater	2 5 0	
Cost of heater	1 0 0	
Cost of iron	15 6	
		17 12 6
Total		£59 19 6

Hire of cooker, £1 10s. 0d.

Current Consumption Costs

Rate per unit: Light, 7½d.; Power, 1½d.

	Light				*Power*				*Total*			
	Units	*Cost* £	s.	d.	*Units*	*Cost* £	s.	d.	*Units*	*Cost* £	s.	d.
January-March	164	5	2	6	480	3	0	0	644	8	2	6
April-June	48	1	10	0	1162	7	5	3	1210	8	15	3
July-September	48	1	10	0	671	4	3	10½	719	5	13	10½
October-December	149	4	13	1½	1001	6	5	1½	1150	10	18	3
Total	409	12	15	7½	3314	20	14	3	3723	33	9	10½

In some instances the cost of installation is rather high owing to the fact that totally enclosed motors were used, and the installation was carried out in 1928-1930.

The next data are the consumption of a number of S.W. & S. Power Company's farms, and comments on the trend of the use of current between the house and the actual farm.

DOMESTIC AND FARM CONSUMPTIONS ON 26 SHROPSHIRE, WORCESTERSHIRE AND STAFFORDSHIRE FARMS

	Farm	*Farmhouse*	*Farm Buildings*
1.	Poultry	About 20%	About 80%
2.	Mixed and Market Gardening	,,	,,
3.	Mixed Average	6,123	405
4.	Mixed	156	40
5.	Mixed Average	2,487	1,218
6.	Mixed	5,521	543
7.	Poultry	64 (e)	1,101 } (e) 20 }
8.	Mixed	749	281
9.	Mixed and Hops	—	771
10.	,,	73	1,756
11.	Dairy and Poultry	2,842	20
12.	Greenhouse	—	2,424
13.	Mixed and Hops	2,281	1,307
14.	Dairy and Poultry	265	2,595
15.	Arable and Cattle	427	166
16.	Mixed and Poultry	2,573	368
17.	Mixed including Hops	2,590	2,801
18.	Poultry and Fruit	1,089	2,764
19.	Poultry (small)	550	272
20.	Poultry	1,161	3,000
21.	Poultry	4,152	4,000
22.	Poultry	629	6,000
23.	Dairy	1,350	1,358

24.	Dairy	1,330	666
25.	Dairy	1,252	8,000
26.	Dairy	3,309	6,000

(e) Estimated.

On 12 farms domestic consumption is higher than farm building and power, on 14 farms power is higher.

Of the 4 dairy farms 2 show farming consumption much greater than domestic consumptions ; 1 shows level consumptions and 1 shows domestic about twice power consumption.

Of the 10 *poultry farms;* the 6 exclusively poultry show :

4 farming consumptions much higher than domestic consumption.
1 farming consumption about half domestic.
1 farming consumption about level with domestic.

Of the 4 *half-poultry farms:*

3 show farming consumption much greater than domestic.
1 shows farming consumption much less.

Of the 10 *mixed farms:*

3 show farming consumption much higher than domestic.
1 shows farming consumption slightly higher than domestic.
6 show farming consumption much lower than domestic.

The 1 arable farm shows farming consumption less than domestic.

The mixed arable farms show similar results.

The 1 greenhouse establishment shows a large farming load.

This sample of farms shows the large variety in consumptions and characteristics which might be expected from the diversity of farming conditions in the country.

Of the 26 farms, data show that 15 have cookers, 18 are using electric motors totalling 236 h.p. an average of 13 h.p. per farm. The range is from 5 to 26 h.p.

7. DATA

This last Section deals with running costs of typical farm machinery, and costs at 1¼d. per unit.

Acknowledgments to various authorities are due for information in compiling this data sheet : The Agricultural Engineering Research Department of Oxford University ; The Agricultural Department of the G.E.C., Ltd. ; The University College of Wales, Aberystwyth ; The Institute of Electrical Engineers for private plant data from a paper by J. A. Sumner, Esq., on "Private Plants and Public Supply Tariffs" and the British Electrical Development Association.

In as many cases as possible I have used my own figures for running costs.

COST OF OPERATING FARM MACHINERY AT 1¼d. PER UNIT

GENERAL FARMING APPLIANCES

Implement	*Size of Motor or Loading Required*	*Cost*	*Work Done Per Unit*
Chaff Cutter ..	2½ to 5 h.p.	Small cutter 6d. per ton Large cutter 4d.	4 cwt. for 1 unit 7 to 8 cwt. for 1 unit
Root Pulper ..	½ to 1 h.p.	⅝d. per ton	2 tons per unit
Cake Breaker ..	½ to 2 h.p.	1¼d. per ton	1 ton per unit
Corn Grinding ..	3 to 14 h.p.	1¼d. per 1 to 1½ cwt. fine grinding	2½ bushels per unit
Corn Crushing and Kibbling	3 to 14 h.p.	3 to 5 cwts. for 1¼d.	7 bushels per unit
Threshing ..	12 to 15 h.p.	10d. to 1s. per hour	7 to 8 units per ton of grain
Water Pumping ..	½ to 3 h.p.	1,000 galls. for 2d.	600 galls. per unit
Dry Mash Mixer	1 to 10 h.p.	2d. to 2½d. per ton	10 to 12 cwts. per unit
Sheep Shearing ..	$\frac{1}{16}$ to ½ h.p.	20 sheep for 1¼d.	1 unit for 20 sheep

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Cost of Operating Farm Machinery at 1¼d. per Unit

Dairy Farming Appliances

Implement	*Size of Motor or Loading Required*	*Cost*	*Work Done per Unit*
Milking Machines	1 to 3 h.p.	½d. to ¾d. per cow per week	½ to ¾ unit per cow per week
Milk Cooler ..	¾ to 5 h.p.	25 - 30 galls. cooled for 1d.	35 galls. per unit
Electric Churn (20-gallon size)	½ to 2 h.p.	80 lbs. of butter for 1d.	100 lbs. of butter churned for one unit
Separator	¼ to 2 h.p.	120 galls. for 1d.	150 galls. of milk for 1 unit
Sterilising Chest	4 to 12 kW.	5d. to 1/3 per sterilising operation	4 to 12 units per operation
Bottle Washing ..	⅛ to ½ h.p.	2,500 bottles washed for 1d.	3,000 bottles for one unit
Water Heating Dairy Size	25 to 50 galls.	2½ to 3 galls. of hot water per unit	
Stunning ..	70 to 250 watts	1,500 animals stunned for 1d.	2,000 animals per unit

Poultry Farming Appliances.

Implement	*Size of Motor or Loading Required*	*Cost*	*Work Done per Unit*
Incubator (small)	200 watts	3 chicks for 1d.	25 units per 100 for 3 weeks
Incubator (large) 3,000 egg capacity	1,200 watts	8 chicks for 1d.	90 units for 900 chicks per week
Electric Brooder ..	200 watts, 100-chick size	¾d. per chick for 4 weeks	½ unit per chick per 4 weeks
Late Hour Lighting for Hens ...	60 watts per 200 sq. ft. floor area, 50 hens	At 8d. per unit for 4 hours per day, 2d. per day	2d. for 30 eggs 120 eggs per unit. Lighting Rate 8d.
Egg Tester ..	60 watts at 8d. per unit	1,500 eggs per hour ½d. per hour	24,000 eggs candled for one unit
Egg Grading ..	⅙th to ¼ h.p.	3,000 to 6,000 eggs graded per hour	15 to 18,000 eggs graded for one unit, or 1¼d.
Plucking	¾ to 1 h.p.	35 birds per hour	35 to 40 birds plucked per unit, or 1¼d.
Heating Water for drinking by chicks	15 watts	65 hours for 1¼d.	65 hours per unit

GENERAL DATA FOR FARMERS

1. *Comparative Prices per H.P. of Petrol, Paraffin and Crude Oil and Electric Motors*

	£	s.	d.
Petrol and Paraffin Engines complete			
2 h.p.	20	0	0
Per h.p.	10	0	0
5 h.p.	42	0	0
Per h.p.	8	10	0
10 h.p.	80	0	0
Per h.p.	8	0	0
Crude Oil Engines Complete:			
5 h.p.	57	10	0
Per h.p.	11	10	0
10 h.p.	90	0	0
Per h.p.	9	0	0
Electric Motors Complete:			
Squirrel Cage Motors—2 h.p. ..	12	5	3
Per h.p.	6	3	4
5 h.p.	19	4	0
Per h.p.	3	16	10
10 h.p.	24	13	6
Per h.p.	2	9	4
Slip Ring Motors :			
20 h.p.	55	2	0
Per h.p.	2	15	2
25 h.p.	62	6	0
Per h.p.	2	10	0

Electric Motors are complete with rails, pulley and control.

2. *Grass Drying Costs from the I.C.I. Handbook on "Grass Drying."*

88 units per ton of dried grass, therefore, at 1¼d. per unit this equals 9/2 per ton. With current at 1¼d. per unit electricity costs 12½% of cost of production per ton and 6% of valued cost of dried product.

3. *Hops Drying Costs from a Worcestershire Farm.*

9 tons of hops dried for 1,107 units of electricity or 123 units per ton of hops or 6 units per cwt. of dried hops.

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4. *Sterilizing Chest Costs. Tests Taken on a Worcestershire Farm.*

With a 4 ft. by 3 ft. by 3 ft.— 36 c. ft. electric sterilizing chest, 10 kW. loading—cold water in reservoir.

45 minutes to sterilize— 7½ units consumed.

When water at 120°F. was place in sterilizer water reservoir 30 minutes to sterilize—5 units consumed.

Tests on a Second Worcestershire Farm.

Chest 5 ft. by 4 ft. by 3 ft. — 60 c. ft., loading 10 kW. Chest unlagged—18 units—time taken 1 hour 50 minutes. With warm water at about 100°F. inserted in chest reservoir.

Same chest lagged—10 units—time taken 1 hour—with warm water at about 100° F. inserted in chest reservoir.

This illustrates the necessity for efficient lagging.

Data of Current Consumptions on Some South Wales Farms.

Table 1. *Consumption of Current* (48 *Farms*)

Groups	*Average No. of Lamps*	*Total Units used*	*Average Units per Lamp*	*Average Units per Farm*	*Average Cost per Farm*	*Average Cost per Lamp*
					£ s. d.	£ s. d.
Under 6 lamps	4	621	19	77	2 3 6	11 9
6-10 lamps ..	8	1,342	18	149	4 13 2	11 7
10-14 lamps	12	2,370	17	215	6 14 8	11 1
Over 14 lamps	22	6,855	15	342	10 14 2	9 5

Data of Motor Costs on Some South Wales Farms.

Table 2. *Cost of Electric Motors* (12 *Farms*)

Power	*No.*	*Average Size h.p.*	*Total Cost*	*Average Cost per Motor*	*Average Cost per h.p.*
			£ s. d.	£ s. d.	£ s. d.
Under 4 h.p. ..	6	1.75	57 0 0	9 10 0	5 9 6
Over 4 h.p. ..	10	5.50	213 0 0	21 6 0	3 18 2

Table 3. *Cost of Installation of Motors*

	Total Cost	*Average Cost per Motor*	*Average Cost per h.p.*
	£ s. d.	£ s. d.	£ s. d.
Under 4 h.p.	20 0 0	3 6 8	1 19 0
Over 4 h.p.	43 1 0	4 6 1	0 15 4

These figures are produced with acknowledgment to the University College of Wales, Aberystwith.

Actual mammoth incubator costs extracted from "Electricity in Poultry Farming" by C. A. Cameron Brown, Esq., with acknowledgments to the author and the Institute for Agricultural Engineering Research, Oxford University.

Cost per chick in terms of units with 80% hatch—over several makes of machines —.058, —.047, —.144, —.024, —.066, —.033, —.034, —.133, —.148 units.

These figures give the following figures of units consumed per 100 chicks produced —5.8, —4.7, —14.4, —2.4, —6.6, —3.3, —3.4, —13.3, —14.8, units.

Cost of one anthracite hot-water table mammoth .052d. per chick or 5.2d. per 100 chicks.

Costs of an oil-heated mammoth with electric fan drive with oil at 7d. per gallon and current at 1d. per unit, the figures are .052d. per chick for oil and .025 units for the fan per chick this equals.077d. per chick or 7.7d. per 100 chicks.

The overall cost of a group of various makes at a farm equalled .146d. per chick with oil at 7d. and electricity at 1d., this equals 14.6d. per 100 chicks.

These figures controvert the statement that oil heated mammoths are much cheaper than electric heated mammoths.

Electricity in the House

One unit of electricity will do the following household jobs: produce 3 gallons of hot water at 150° F. from a water heater; heat a 1,000 c. ft. room for 1 hour; boil a 3-pint kettle 5 or 6 times; do a day's cooking for one person; toast 50 to 60 pieces of bread; run a vacuum cleaner for 4 hours; drive a washing machine for 4 hours; heat a domestic iron for 3 hours; run a bowl fire for 2 hours; make 60 cups of coffee; heat your shaving water for 1 week; work a sewing machine for 21 hours; light a 60-watt lamp for over 16 hours; light a 25-watt lamp for 40 hours; keep the motor car warm for 10 hours; run a house fan for 25 to 30 hours.

ELECTRIC MOTORS FOR FARM MACHINERY

By F. E. Rowland, A.M.I.E.E.
(*Manager, Agricultural Department, The General Electric Co., Ltd.*)

Introduction

The convenience of electric motors is such that their use for driving machinery in farm buildings is assured, provided electricity is available at suitable tariffs. There is a great deal of misconception as to the price at which it is economical to use electric drive, and for ordinary purposes tariffs up to 2d. a unit are economical in use. The great advantages of electric motors compared with other sources of power, such as ease of starting from any position and at any time, elimination of fire risk, the facility with which they can be placed in any position owing to the absence of fumes, vibration and noise, and the lack of the necessity of adjustment or periodical overhaul, appeal readily to farmers. Electric motors also have the feature that their efficiency does not drop appreciably when they are only used at low loads, and consequently the cost of running is proportional to the amount of work which is done, whilst their constant speed and absence of vibration lessens the wear and tear on driven machines and ensures a uniform standard in the finished product. Absence of fumes, vibration and noise, are particularly valuable features on dairy farms, eliminating the risk of contaminating milk or disturbing the cows, whilst constant speed ensures the best results with such appliances as milking machines. For pumping electric drive provides a service which requires little attention, and with float switch control fully automatic supply is provided.

With the great development in the distribution of electricity in rural areas which has taken place in recent years, the number of motors which have been installed on farms has increased greatly, and the rate of increase should be even greater in the future. Statistics of electric motors and engines installed on farms are unfortunately only available up to 1931, the following figures being taken from "The Agricultural Output of England and Wales, 1930-1931."

Number of Agricultural Engines or Motors returned as used on farms in England and Wales—1925-1931.

	1925	1931	*Increase or decrease*
Steam	3,731	2,246	−40%
Oil or petrol	56,744	65,725	+16%
Electric	700	2,475	+254%
Tractors for stationary work only	2,116	2,466	+17%

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Owing to the great increase in electrical development in rural areas since the date of this report, the number of electric motors installed at present must exceed the above figures very largely.

The use of electric motors on farms has increased greatly throughout the world of recent years. This is exemplified in the case of Germany where the increase from 1925 to 1933 was 56%—from 746,000 to 1,169,000. In that country 93% of agricultural power units are now electric and 80% of farms are connected to supply mains (Hamburg World Economic Archives).

Types of Motors

Electric motors used on farms fall roughly into three categories :

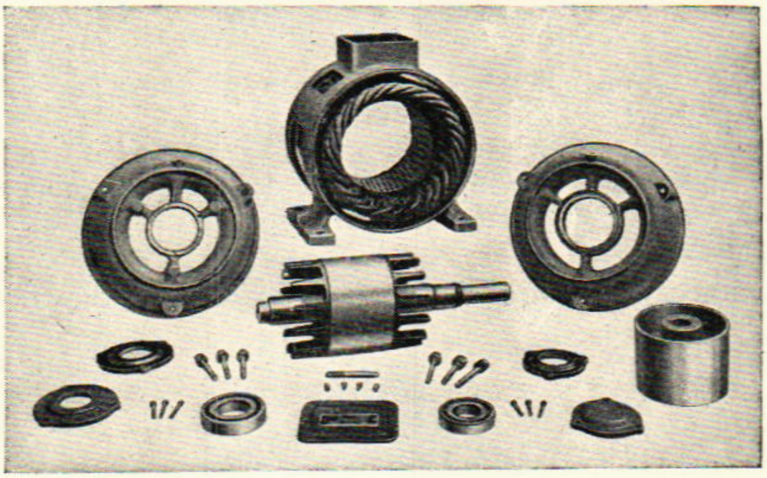

Fig. 1. Components of squirrel cage induction motor showing simple and robust construction.

Single Phase	Up to 1 h.p.
Three Phase, Squirrel Cage ..	1 h.p. to 7½ h.p.
Three Phase, Slip Ring	Over 7½ h.p.

The type used in specific cases depends upon the requirements of local supply authorities, and is largely governed by the maximum starting current permissible, which may be influenced by the position of a farm in relation to the electricity distribution network. For instance, the requirements might be less exacting for a farm supplied from its own transformer than for one situated at the end of a long feeder supplying several consumers. Small single-phase machines may be connected to the same supply as the lighting and heating installation and are employed for pumps, incubators, bottle washers, etc. Three-phase squirrel cage motors are the simplest in design and maybe used for the majority of barn drives, but when starting current has to be limited with higher powers, slip-ring machines must be employed. Although it is usual for motors of

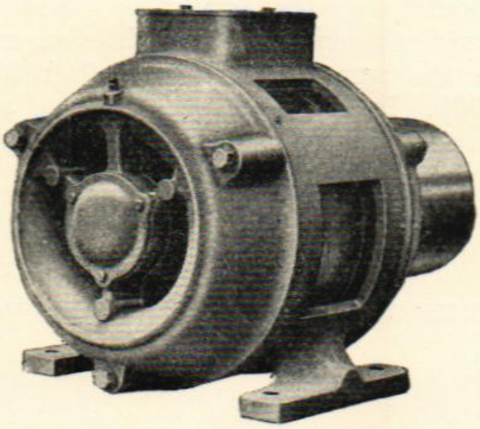

Fig. 2. Protected type squirrel cage induction motor.

over 1 h.p. to be three-phase, sometimes only a single phase supply is available, which necessitates the employment of a more expensive type of motor.

The rating of power output of an electric motor depends on its

Fig. 3. Totally enclosed slip-ring induction motor.

temperature rise; consequently a standard protected machine in which there is ample provision for ventilation will give a greater output than a totally enclosed motor of the same dimensions. Totally enclosed machines, therefore, are considerably larger and more expensive than protected type. A recent introduction is the cowl-cooled motor in which a totally enclosed design is used, with a cowl containing a fan, covering part of the frame. This arrange-

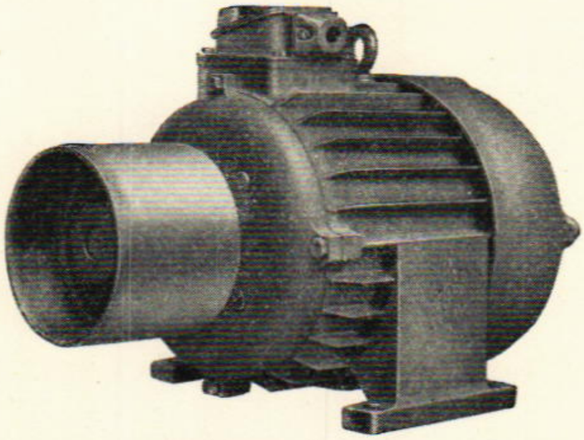

Fig. 4. Cowl-cooled squirrel cage induction motor.

ment provides additional ventilation and results in the size and price of the motor being less than a totally enclosed machine.

The difference in prices between various types of motors and variation in size between protected and totally enclosed machines is shown below :

Comparison between Squirrel Cage Protected and Totally Enclosed, and Slip-Ring Protected Motors.

400/440 volts, 3-phase, 50 cycles 960 r.p.m.

H.P.	*Squirrel Cage*				*Slip Ring*	
	Protected		*Totally Enclosed*		*Protected*	
	Frame	*Price*	*Frame*	*Price*	*Frame*	*Price*
		£		£		£
3	A	12	C	18	C	30
5	B	15	I	24	C	30
7½	C	18	K	32	D	33
10	D	21	O	41	G	37
15	H	28	Q	58	H	44

Squirrel Cage motors include star-delta starters, pulley and slide rails.

Slip-Ring Motors include rotor and stator starting panels, pulley and slide rails.

The figures are typical for comparison.

As an example it will be observed that a 3 h.p. totally enclosed squirrel cage motor has the same frame size as a 7½ h.p. protected type and that the prices of these two types are similar, whilst the use of a slip-ring in place of a squirrel-cage motor necessitates a considerable increase in price.

Control and Overload

Fig. 5. Push-button direct-to-line starter.

Starting and control of electric motors is extremely simple, in many cases being effected by operating a switch or pressing a button, whilst even the most complicated operation consists only of moving a lever through two positions. The type of starter adopted

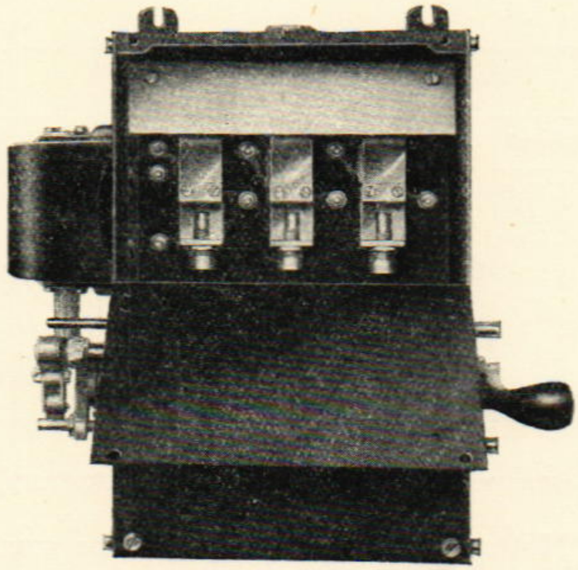

Fig. 6. Air break Star-Delta starter showing hinged lid.

is governed by the maximum current it is permissible to take from the mains when starting. It is usual to start motors up to approximately 3 h.p. by switching them direct on to the line, and motors

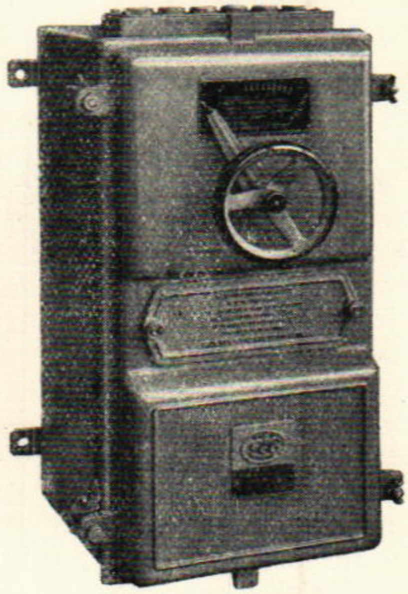

Fig. 7. Air break rotor and stator starting panel.

up to 7½ h.p. may be controlled by star-delta starters, whilst machines of larger sizes are of the slip ring type with rotor and stator starting panels. Typical starting characteristics of standard 3-phase motors are shown below :

Type of Motor	*Method of Starting*	*Starting Current*	*Starting Torque*
Squirrel Cage	Direct Switching	Approx. six times full load	Approx. 130% of full load
,,	Star-delta	Twice full load	40% of full load
Slip Ring	Rotor and Stator	Full load	Full load

Electric motors are able to withstand considerable temporary overload, the following figures being typical :

Overload	*Time*
25%	15 Mins. to 2 Hours according to h.p. and speed
50%	1 Min.
100%	15 Secs.

The provision of suitable protection in starting equipment ensures that motors are disconnected from the supply in the event of excessive overload ; this not only protects the motor but also the driven machinery from damage. The inclusion of a no-volt feature ensures that in the event of an interruption to the supply to a motor, the starter is tripped and when the supply is resumed, the motor will not start again until the starter is operated. This prevents the possibility of accident through machines being re-started from a remote situation. All motors with a rating exceeding $\frac{1}{2}$ h.p. should be provided with overload and no-volt protection.

Motor Speeds

An electric motor is essentially a fast running machine, and standard designs are available from 580 r.p.m. to 2800 r.p.m., the price for slow speeds being greater than for high. For the types used on farms, the most economical speed as regards the first cost is approximately 1400 r.p.m. However, as the majority of farm machines run at slow speeds, it is usual for motors on farms to be of 960 r.p.m. and this reduction has not a very material effect on the first cost.

Maintenance

The maintenance of electric motors is extremely simple, all that is required being a little grease in the bearings at intervals of a few months and a periodical examination every six or twelve months, according to the situation, to ensure that the interiors are not excessively clogged with foreign matter, which can generally be removed by blowing out with a pair of bellows.

Fixed Motors

In this country, the majority of farms are equipped with counter-shafting from which existing barn machinery, pumps, etc., are driven, and when electricity becomes available it is the usual practice to instal an electric motor to drive this shafting when the existing engine requires replacing. Standard protected machines

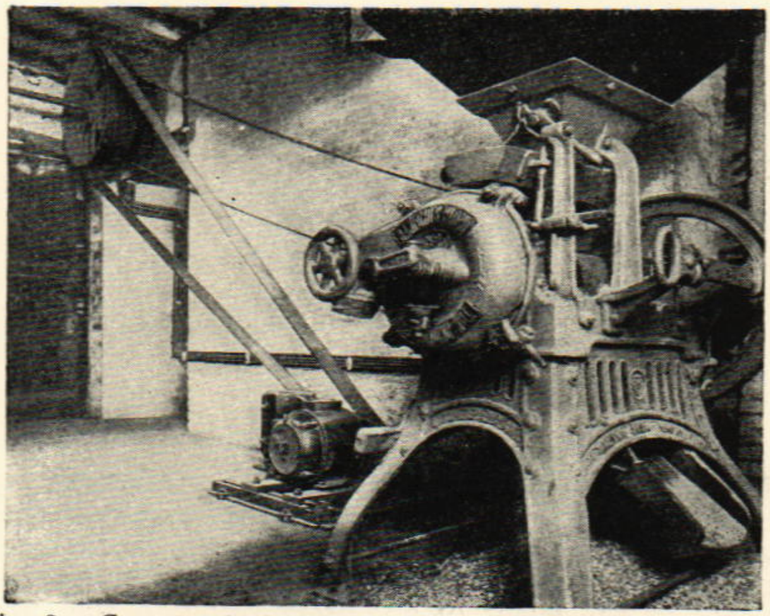

Fig. 8. Countershaft drive. Starter mounted on motor.

are generally used, running at about 960 r.p.m., although when such motors are working in very dusty or dirty situations, it is recommended that they should be totally enclosed, pipe ventilated or cowl cooled.

Portable Motors

Portable motors are employed when one source of power is required to drive various machines in different parts of farm buildings, but their use is not as widespread in this country as is sometimes imagined. The equipment should be of robust construction and a satisfactory compromise established between portability and stability when driving. Two wheeled trucks may be employed up

Fig. 9. 5 h.p. portable motor and countershaft on two-wheeled truck.

to 7½ h.p., whilst over this size, due to the greater weight, four-wheeled construction is preferable. Although the majority of designs are a combination of trucks on which the motor and control gear are mounted, there is one notable exception, namely the

"Drumotor" in which the whole unit is in the form of a steel drum,

Fig. 10. 5 h.p. portable farm "Drumotor" in transit.

which enables it to be transported with particular facility. When a portable motor is to drive several machines working at different speeds and the full variation cannot be obtained by means of various sized pulleys, slow speed countershafts or gearing with interchangeable pulleys may be incorporated in the portable unit.

For threshing in yards and other heavy duties when portable

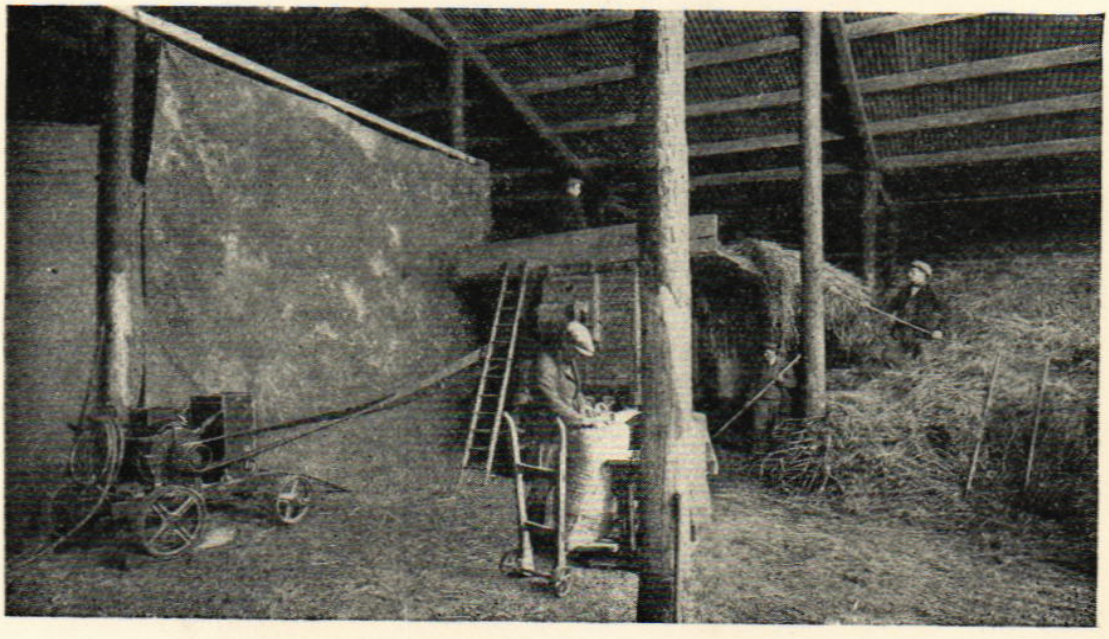

Fig. 11. 20 h.p. heavy duty portable motor driving thresher.

motors are required, equipment of 15 h.p. to 30 h.p. of heavy construction with a four-wheeled bogey is employed.

When it is desired to move a motor only at occasional intervals and the elaboration of a portable unit is not essential, a useful compromise is that of a " Skidmotor " in which the motor and

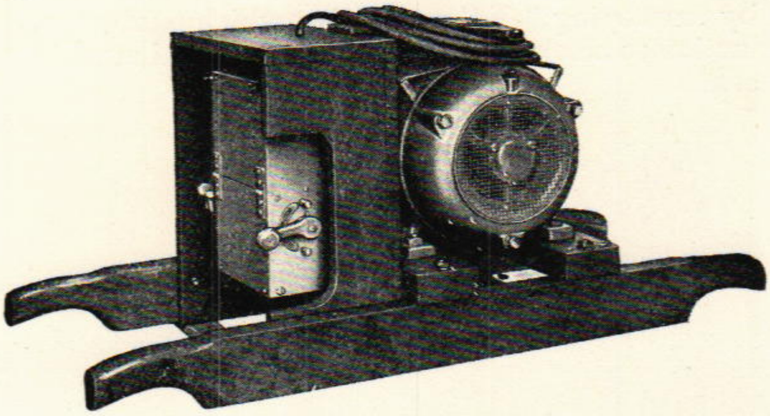

Fig. 12. 5 h.p. " Skidmotor."

control gear are mounted on wooden skids. These units, although not as readily transported as portable motors, have the advantage of being less expensive and are easily moved when the occasion requires. The design of portable motors should be sufficiently robust to stand up to rough usage and the electrical equipment and connections of a quality to ensure reliability and safety. Flexible leads should be kept as short as possible by the provision of plug connections adjacent to the positions where the motor is to be used.

Direct Coupled and Built-in Motors

Machines with direct coupled motors occupy a minimum of

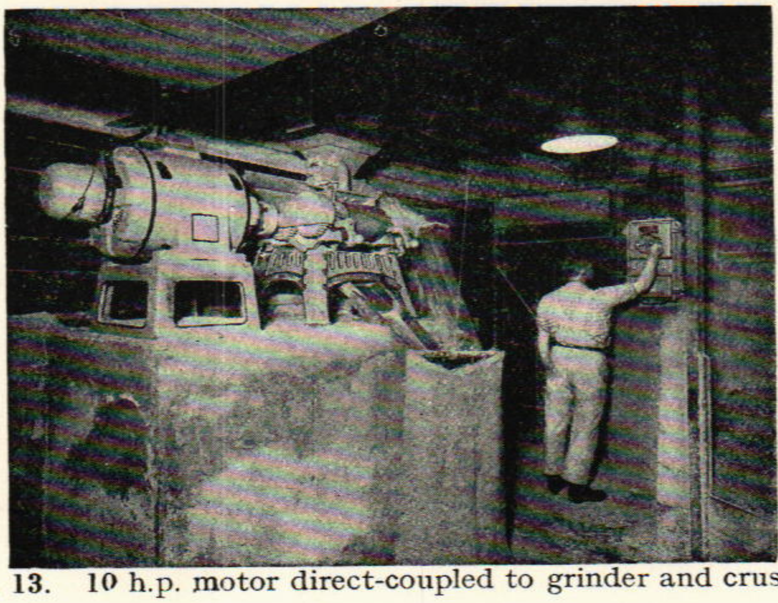

Fig. 13. 10 h.p. motor direct-coupled to grinder and crusher.

space, whilst transmission losses associated with belts, counter-shafting and gearing are eliminated. When machines are used sufficiently to warrant the provision of a separate motor, this arrangement may be used with advantage, whilst when the expense of direct drive is too great a very satisfactory compromise may be effected by employing " V " rope drive which enables considerable speed reduction to be obtained with the motor and machine mounted at close centres.

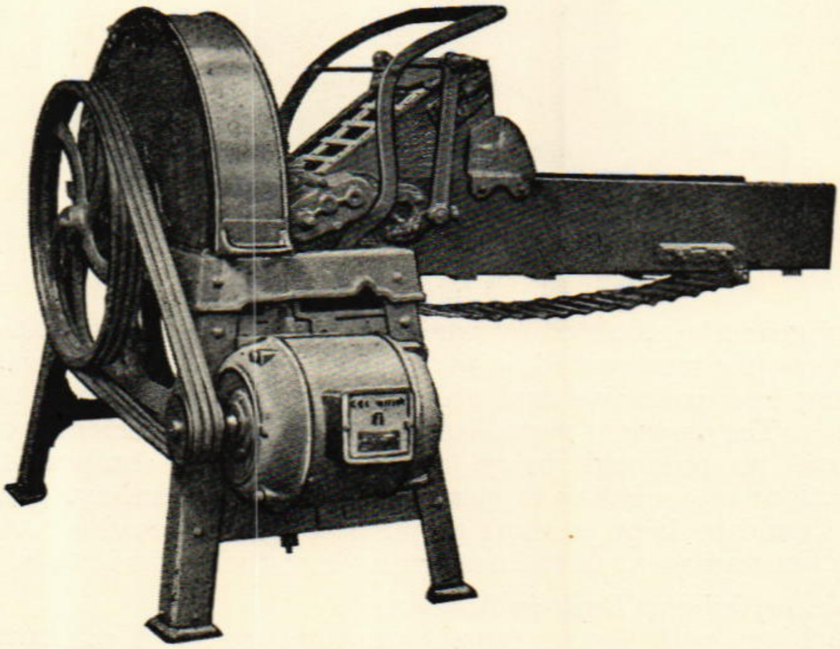

Fig. 14. Chaff cutter with vee rope motor drive.

A further step in the evolution of electric drive is the provision of machines with motors built into them and forming part of the main design. This practice is, of course, common in other industries where electrification is more widespread and has been established for longer, and will no doubt be adopted in the agricultural industry in the future. Machines of this description have been developed in France where there is a considerable market amongst a large number of small peasant farmers. To secure the maximum benefit from this development, it will no doubt be necessary to redesign many machines, so as to obtain the greatest efficiency from the high speeds and smooth torque obtainable with electric drive. Hammer mills and cream separators lend themselves readily to this arrangement on account of their high speeds, but such machines as chaffers and pulpers which are essentially slow running would require considerable modification.

Power and Output

The size of motor and output for various typical barn machinery are shown in the table below :

Machine	*Machine Pulley Speed r.p.m.*	*Size of Motor h.p.*	*Output per h.p. per hour*	*Output per unit of electricity*
Cake Breaker	160	2–4	20 cwt.	22 cwts.
Chaff Cutter :				
Self Feed	120–250	2–8	7 ,,	8 ,,
Hand Feed	120–250	2–8	3½ ,,	4 ,,
Crusher ..	400–600	2–12	5½ bushels	6 bushels
Grinder ..	400–600	2–12	2 ,,	2½ ,,
Kibbler ..	400–600	2–12	7 ,,	8 ,,
Mixer	140	1–5	20 cwts.	22 cwts.
Root Cutter	80–120	2–4	35 ,,	39 ,,
Thresher ..	1,000–1,200	5–25	4 bushels	4½ bushels

The figures given above apply to types of machinery generally in use and may vary in some instances.

FARM WIRING and EARTH LEAKAGE

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It is a remarkable fact, but none the less understandable, that the average farmer pays more attention to the purchase of a minor implement than to the quality and kind of his electrical wiring installation. The installation on a fair-sized farm will have a cost many times that of most implements and may be as much as or more than that of a tractor. It will be expected to outlast the implement or the tractor by many years and will be expected to give no trouble. Notwithstanding this, the farmer often pays but perfunctory attention to the choice and layout of the installation and contents himself, where he has gone so far as to invite alternative estimates, with choosing the lower.

I wish that this state of affairs was due to well-placed faith in the integrity of wiring contractors and their materials, but this is not the case. Perhaps this should be explained by saying that where a firm has reached the status of " contractor " it has usually a reputation to maintain and that satisfactory dealing may be expected, but that there are everywhere small firms who are capable of only inferior work—sometimes unscrupulously so but often through well-meant incompetence.

There are certain fundamental rules in approaching this problem of wiring :

(1) Always get two or more alternative estimates.

(2) Always suspect the all-in estimate. A good estimate should be detailed. The smart estimator who gives the buildings a hurried look and produces a figure while you wait may impress but it would be unwise to trust him. If he has over-estimated he nets a good profit, but if he finds that costs are mounting, he takes steps to skimp the job. The good firm does not gamble but measures up the job, apportions the cost and adds a standard percentage for profit. By detailed estimates we do not necessarily require that every wiring point should be priced, but every point should be specified for both position and for material.

(3) Always go over the ground with the firm's representative and show him where you want the various points and outlets to be : if he should suggest modifications, take the trouble to be satisfied that this will suit you.

(4) Always check over the estimate on the site and see whether the points and services scheduled agree with your original understanding with the firm's representative ; even a good firm may make a mistake.

(5) Never accept the lowest estimate blindly without ascertaining in writing that the materials used are of equal standard to those

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specified in the higher estimates. Suspect any estimate appreciably lower than the rest ; it may be genuine, but be sure.

In very many cases where the contracting firm has a high reputation and experience in farm work, there should be no occasion for the farmer to interest himself in either the materials or the application of them. Unfortunately, however, there are firms capable of excellent workmanship but having no experience of farm work, and small electricians who have no ideas beyond conventional lead wiring. It is as well, then, for the farmer to have some idea of the materials best suited to his circumstances and on which he can insist.

It is essential to be clear as to the main conditions and functions of a wiring system. We may assume that all farm supply is alternating current at 230v. single phase and 400v. three-phase. For technical reasons the supply company connects one side of the single phase (i.e., one wire) and the neutral wire of a three-phase supply to earth. This means that one wire—the live wire—of the pair in every single phase circuit and the three live wires in the three-phase circuit are at a pressure of 230 volts above earth ; there is also, of course, a pressure between the wires themselves. Unwanted and dangerous current will flow if either of the wires are brought into contact or if a live wire touches earth or any part of a building or structure which is in through contact with earth. In a dwelling house there require to be water or gas pipes in the room or a stone floor before this condition is possible but in the farm buildings there are usually stone walls or floors throughout, or bare earth, so that contact with " earth " is an imminent possibility.

The wiring system must provide insulation to prevent such unwanted contact and in all modern systems this consists of a thin coating or shell of rubber round the wires. This may be of pure rubber or of vulcanised india-rubber or of a combination of both. To meet the temperature conditions over the farm, vulcanised indiarubber (V.I.R.) is preferable. Any other wrapping or sheathing is extra to the insulaton and is for some other purpose, such as mechanical protection. A wiring system which confines itself to its primary function, that of insulating its conductors, is known as an " all-insulated " system and is supplied by wiring carried out in one or other of the family of tough rubber-sheathed cables known generally as cab-tyre sheathed (C.T.S.) cable, and used in conjunction with fittings and switches of insulating material such as bakelite or porcelain. A lighting system can be all-insulated but where there are motors a hybrid system is used and is described later. Another " all-insulated " system which is suitable for special conditions is taped and braided V.I.R. insulated cable carried on porcelain cleats.

The " earthed " system of wiring is based on the principle that if there should be a breakdown of insulation it is better to afford it an immediate and certain path to earth and so blow the fuses than to leave it to a casual and perhaps dangerous contact on the part of a workman to do so. For this purpose the insulated conductors are themselves enclosed in a metal casing which is made electrically continuous throughout the system and at one or more points brought into good contact with the ground. This is, in theory, an excellent idea, but depends for its success and its safety on the metal casing being in proper electrical continuity. The conditions on a farm are such—damp, fumes, cold and heat—that everything tends to destroy or at any rate to spoil that electrical continuity ; metal rusts or corrodes and high resistances are introduced at every join. An "earthed" system with an imperfect earth casing is more dangerous than an all-insulated system ; when a leak takes place the leakage potential is spread out over an exposed area between two bad joins and there is more chance of accidental contact.

Generally speaking, then, an earthed system is to be avoided on the farm but if the idea of continuous earth protection appeals it can be achieved in one of three ways :

(1) By a tubing system in which V.I.R. cables are drawn into galvanised steel tubes or zinc impregnated rustproof (Z.I.R.) tubes and all pipe joints *screwed*.

Any sort of grip joint is to be avoided as is black-enamelled tubing. The joint boxes, etc., should be cross-bonded to avoid the effect of rust in the cut thread. Only a first-class firm can make a good job of this system as the lay-out must be planned to prevent free moisture entering the system and yet to allow ample ventilation to carry off condensed moisture.

The big advantage of this system is that the cables are almost completely protected from mechanical damage and on a fault developing, a section can be easily withdrawn and replaced.

(2) By a metal-sheathed cable system incorporating a continuous bonding wire inside the metal sheath. This is jointed up inside the joint boxes when the power wires are joined. This makes a more permanent earthed circuit than relying on the sheathing itself, clamped at the various boxes. This system depends for long service on keeping damp out of the ends of the cut cables and to do this each joint box should be packed with plastic compound ; the number of cut ends should be kept to a minimum by "looping-in."

This system is generally regarded as being strong mechanically but this is a mistaken view, the lead offering little real protection from mechanical impact and is subject to corrosion from stable fumes, etc.

(3) By a C.T.S. system with a third continuous earth wire run inside the sheathing and jointed inside the joint boxes, and with plastic compound packed into the boxes.

It will have been gathered that an earthed system is not recommended for farm wiring and this is actually so. The conditions are so likely to cause deterioration in the earth circuit that it is felt that even a well-built installation would sooner or later become dangerous from that cause. An improvement is effected by using the internal earth wire but it is considered that this step is quite unnecessary. It is recommended that for the wiring of farm buildings an " all-insulated " system be installed, using C.T.S. or similar type cable and all fittings and fixtures of bakelite or similar insulating material ; all joint boxes or switch boxes should be packed with cold plastic compound. The cable used should be of 600 megohm grade—the 2,500 meg grade is unnecessary—and should be of " Vicma " standard, this indicates the Cable Makers Association grade, using V.I.R. for the insulation, which is preferable to pure rubber for farm conditions. If this is specified and carried out there need be no fear of the materials being faulty.

If power is used the installation cannot be altogether " all-insulated " since the motor casings and starter boxes will be of metal which must be earthed. This can best be done by running an individual earth wire to a separate earth on each group. If there is any difficulty in making a good earth—or indeed in any case—an earth leakage switch should be fitted to the motor. This will not add so very much to the cost but will add considerably to the general safety.

The C.T.S. covering the cable is very strong indeed and affords substantial protection from mechanical damage as well as being impervious to damp or the effect of ammonia fumes. Intelligent running of the cable and placing of the switches—admittedly breakable if of bakelite or porcelain—will add considerably to freedom from damage and inconvenience.

It is probably the one real drawback to C.T.S. that on exposure to daylight it hardens and ultimately cracks, a condition which only becomes serious if the cable is moved or if there is much damp about. Then, too, most farm-building interiors are far from enjoying a state approaching anything like honest daylight. To be on the safe side and to make the very best job, use should be made of a type of C.T.S. cable having an outer braiding which obviates the difficulty raised by exposure to light.

All flexible leads to appliances *must* be of C.T.S. cable and all suspended light flexes *should* be. The ordinary twisted silk-covered flex is quite unsuitable. Before accepting the materials, inspect the type of plug offered. You will have to wire in most of the portable appliances for yourself and some types of plug are very difficult indeed to wire properly. Choose a type which is easily wired. These plugs will have three pins, the large one being that connected to the earth wire. Unless the casing of the appliance is made of insulating material, bakelite for instance, a three-wire flexible will be required and should be specified when the appliance is bought. The plug, when opened, will probably have a label showing which of the pins is " live " and which " neutral "—alternatively the live pin may be coloured red for part of its length. The red covered wire in the flexible should be connected to the " live " pin and the black to the neutral pin. The white wire goes to the earth pin.

So far as the farmhouse is concerned, there is no difference from any other type of residence and any of the standard systems, in first-class materials, of course, may be used. Enamelled tubing or lead-sheathed systems are probably more generally preferable. The use of Nonazo (Non-Association) grade of cable is allowable and effects a small economy.

Amateur wiring is strongly to be discouraged ; so many attempts result in appalling results, and it is, indeed, often difficult to point out the defects to the proud perpetrator. But that should not discourage taking an interest in the installation, both before and after its execution. Trouble will often be minimised by anticipation if regular insulation tests are carried out. This should be done once a year and the cost of bringing a man out to do it can be reduced by arranging with one or two neighbours to have theirs done at the same time. In the same way, since travelling is one of the serious expenses in the contractor's estimates, a substantial reduction in wiring costs can usually be arranged by one or two adjacent farms having their wiring done at the same time by the same firm.

Leakage Protection

Raising the question of protection from leakage potentials is not, as so often assumed by the lay press, to draw attention to the dangers of using electricity. It is merely to explain how one source of danger, inseparable from the use of electricity—as there are equal dangers inseparable from the use of gas, oil, petrol, etc.,—is being met and overcome.

Wherever there is metal work, the casing either of a wiring system or of an appliance, likely to be charged with a dangerous potential on a breakdown of insulation taking place, it is necessary to provide some means of cutting off the supply to the weak point. The established method has been to connect all exposed metal work to earth so that when the fault develops the resultant rush of current blows the fuse and so isolates the faulty section. Unfortunately in rural areas where resort must be made to local " earths " the resistance of these is often so high that sufficient current will not flow to blow the fuse. The maximum pressure to earth is 230 volts and as it is nothing uncommon to have earth resistances of 50 ohms and more in dry weather, it is obvious that a leakage current of only some 4.5 amperes will flow ; this is insufficient to blow the so-called 5 amp. fuses which are usually fitted to lighting and light appliance circuits. It will be seen how little chance there is of blowing the bigger fuses on the power circuits requiring 20, 30 or 40 amps.

Of recent years, however, there has been developed the " earth leakage trip " which is a device actuated by the potential impressed on the metal work by the leakage so as to bring out the switch when a certain potential on the exposed metal work is reached. The leakage circuit incorporates a very sensitive trip coil which requires only a few milliamperes to flow before bringing out the switch and so rendering the defective section dead. The coil itself requires a potential of some 20 to 30 volts and a circuit of 20 to 30 milliamperes to actuate it ; this means that with a 50-ohm earth resistance the switch will operate with a leakage potential of about 30 volts. In practice, however, there is much more likelihood of encountering a full pressure to earth of 230 volts, which means that the trip will operate even if the total earth resistance, including the substation resistance, is something over 5,000 ohms. Thus the use of one of these switches procures absolute safety under practically every rural condition.

The use of the earth leakage trip has a bearing on the wiring system to be installed. If an all-earthed system is used and if it is in good condition, any leakage potential on one part of the casing will immediately be spread over all the system and every leakage trip will come out. In practice on a system of this sort only one leakage trip would be fitted at the mains end. This would mean, however, that if any leak took place the whole installation would be out of action, which might be highly inconvenient. With the all-insulated system, however, each motor or appliance would have its own leakage trip switch and a fault developing in the apparatus and causing a leakage potential on its casing would only cut out the supply to the apparatus. There is a strong possibility that leakage trip switches will have their value more fully recognised and their application extended. Keeping this in mind as a future, if not an immediate condition, one would certainly specify an all-insulated installation using a C.T.S. or other tough rubber cable.

ROTHAMSTED MEASUREMENTS COMPARING FUEL AND ELECTRICITY AS A SOURCE OF POWER

(*By G. H. Cashen, M.Sc., and Dr. B. A. Keen, F.R.S.*)

Introduction

THERE are few farms that do not use to-day some form of power—either tractors or stationary oil engines or both—for the various operations in and around the farm buildings. The extension of rural electrification is providing more and more farmers with the opportunity of using electric motors instead of internal combustion engines for this work. While electricity has a number of very definite advantages, particularly for lighting, cleanliness, and simplicity and convenience in operation, to which the farmer can assign some money value, his main concern is to know the relative costs of electric and mechanical power on his own farm for his average yearly requirements in grinding, pulping and other farm operations. For this purpose he must first ascertain the relative power consumption of electricity and fuel for the same job of work; e.g., the number of units of electricity and the number of gallons of fuel required to grind a ton of barley to a given fineness. There is already information available from which he could ascertain these comparative figures. The manufacturers of barn machinery can say what horse-power the machine requires for efficient and economical running; and, in their turn, the electric motor and internal combustion engine makers can give the electricity or fuel consumption of a power unit delivering the required horse power.

Probably most farmers would have a natural suspicion that such figures erred on the side of optimism, and that under normal farm conditions a lower efficiency would be achieved. Whether this be so or not, it is clear that direct comparative measurements under farm conditions of the quantity of electricity and of fuel consumed for the same operations will be a useful guide to farmers. This is the purpose of the Rothamsted measurements; to show for typical operations how many units of electricity are equivalent to one gallon of paraffin or petrol or heavy oil. With this figure, and knowing also the quantity and cost of the oil fuel he already uses, the farmer who contemplates changing to electricity could compute what the equivalent quantity of electrical power would cost him. This is, of course, putting the matter in its simplest form; the final comparison must include such comparisons as the cost of equipment, depreciation and repair and, in the case of electricity, any charge for bringing the supply to the farm; the money value the farmer puts

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on the undoubted conveniences of electric power, already mentioned above, must also be taken into account.

The Rothamsted measurements are made under the normal conditions of farm work, except that accurate and detailed records of fuel and electricity consumptions are taken, together with numerous subsidiary records required in the final calculations. In order to reduce the effect of irregularities due to variations in the quality of the farm produce (e.g., as between the top and bottom of a stack in threshing experiments) the usual procedure is to use the electric motor and the internal combustion engine alternately in short periods, treating each period as a separate experiment.

The experiments to date have been on threshing wheat, oats and barley, and on the grinding of barley for meal.

Threshing Experiments

Stacks of oats, wheat and barley built close to the farm buildings were threshed. Three sources of power were used :

(1) A General Electric Company Witton 20 h.p. portable motor ;

(2) A new International Harvester Company 10-20 h.p. tractor, that had done about 100 hours' farm work before these experiments ;

(3) An old International Harvester Company tractor in use at Rothamsted since April 1928 and still in fair condition after 7,000 hours' work.

Sixteen two-hour runs were made, of which seven were with the motor, six with the new tractor and three with the old. Special arrangements were made to obtain accurate measurements of the electricity, and the fuel and lubricating oil used in each experiment, and in addition records of the following were taken :

(1) the weight of produce as first and second-grade grain, offal, chaff, cavings and straw ;

(2) time and labour required to line-up motor or tractor with the threshing machine ;

(3) the cause and duration of any stoppage ;

(4) revolution speed of driving pulley and thresher drum ;

(5) petrol required for starting and warming up the tractor before turning over to paraffin.

The Marshall threshing machine used has a drum width of 48 in. and the optimum speed of the drum is given as 1,240 r.p.m. In our experiments the speeds were somewhat lower. Experiments were done at various speeds ranging from 1,064 to 1,206 r.p.m. This variation was obtained by suitable combinations of the pulleys on the thresher and the driving machine.

A summary of the results is given in Tables 1, 2 and 3, in which any differential effect due to the kind of crop used is ignored. The threshing rate was about 2 tons of grain per hour. Although there were certain small differences in the power consumptions for barley, oats and wheat, these differences were not in the same order for each form of power, and it is not possible to disentangle them from changes in the other variables, such as drum speed.

Table 1

Electric Motor:

Expt.	*Thresher Drum r.p.m.*	*kW.*
3	1,066	7.5
4	1,068	7.7
12	1,078	7.15
8	1,080	7.95
9	1,204	8.45
16	1,204	7.85
13	1,206	9.17

Output : 2 tons of grain per hour.

Table 2

New Tractor:

Expt.	*Thresher Drum r.p.m.*	*Paraffin Consumption gallons per hour*	
7	1,067	1.30	1.35
1	1,074	1.41	
11	1,151	1.45	1.34
15	1,154	1.23	
2	1,206	1.52	1.48
6	1,203	1.43	

Output : 2 tons of grain per hour.

Table 3

Old Tractor:

Expt.	*Thresher Drum r.p.m.*	*Paraffin Consumption gallons per hour*	
5	1,064	1.18	
10	1,128	1.39	1.31
14	1,134	1.37	

Output : 2 tons of grain per hour.

Table 1 shows that for the four experiments at the lower drum speed (1,068-1,080 r.p.m.) the mean consumption was 7.6 kW. and 8.5 kW. for the higher drum speed (1,204-1,206 r.p.m.). The general mean for the seven experiments was 8.0 kW.

Table 2 shows that for the new tractor the average paraffin consumption was greatest for the highest drum speed. The mean value for the six experiments was 1.39 gallons per hour, a figure slightly in excess of the consumption with the old tractor, 1.31 gallons per hour (Table 3). It is probable that the carburettor

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adjustment made at the factory gave an unnecessarily rich mixture, for it will be noted that experiment 15 (table 2), in which the setting was altered to give a weaker mixture, gives a lower value for paraffin consumption than in any of the other five experiments. However, it may be assumed that most farmers would not alter the carburettor adjustment made at the factory, so for our present purpose we can take the weighted mean of the nine experiments made with the tractors as a fair value for the paraffin consumption under the normal farm conditions at Rothamsted ; this value is 1.36 gallons per hour. Hence 8 kW. hours are equivalent to 1.36 gallons of paraffin in these conditions, or 10 kW. hours are equivalent to 1.7 gallons of paraffin. In using this relationship for working out comparative costs, account must also be taken of the petrol required to warm up the tractor, about 1¼ pints, and the consumption of lubricating oil which, if the tractor manufacturer's directions are followed, amounts to just under one pint of oil each two hours.

The careful measurements of the different grades of threshed produce and a close examination of their condition gave no support for the statement, sometimes advanced, that the smoother torque of the electric motor produces a better sample of threshed grain. The percentage of second grade grain and offal was slightly higher with the motor, and although a constant feeding rate to the thresher was aimed at, the rate was some 4 per cent. lower with the motor due, it may be suggested, to the psychological effect of the quieter running. But these differences are not significant and may well be due to variations in factors such as stack height, sheaf weight, and the fact that any one crop provided only sufficient material for four to five experiments.

No stoppages during the experiments occurred to the motor or tractor ; the most frequent trouble was the breaking of the string in the straw trusser.

It is important to realise that in these experiments the output of both the motor and tractors was only about 10 h.p. so that they were working at only 50 per cent of their full load. The efficiency of a motor falls less rapidly with reduced loads than that of an internal combustion engine. Hence, if smaller power units had been used, say 10-12 h.p., which would have worked under full load, it is very probable that a lower figure than 1.7 gallons for the paraffin equivalent of 10 kW hours would have been given.

This raises, however, a very important point in farm practice. Even on the most efficiently run farms, the tractor spends only a small fraction of the year in cultivating, harvesting and haulage work. While it may be inefficient—in the engineering sense of the term—to employ it for driving barn machinery that requires only a fraction of its available horse-power from the viewpoint of farm practice the matter appears in a different light. The farmer is "wasting" only the difference between the fuel consumption of the tractor and a smaller engine, but against this he saves the capital cost of the smaller machine. It would be interesting to know how far similar considerations apply to electric motors.

In the World Tractor Trials held at Oxford in 1930, the average consumption at half-load was 1.6 gallons of paraffin per hour. The International tractor working at half-load used approximately 2 gallons of paraffin per hour, as compared with our figure of 1.36 gallons. The two values may not be strictly comparable, but part of the difference is undoubtedly attributable to the improvements in tractor design since 1930.

CALCULATION OF COSTS (THRESHING)

Although the purpose of the Rothamsted experiments is to compare equivalent consumptions of fuel and electricity ; the use of these figures is to provide the basis for comparing the relative costs of the two forms of power. The electrical installation at Rothamsted is designed for both experimental and normal farm work, hence our own costings data would not directly apply to commercial farm conditions. In the following calculations typical commercial farm conditions for a farm of similar size and cereal acreage to Rothamsted are assumed.

Methods of Costing

(1) *Starting and Running Costs.*

The only labour costs which have been considered are those for lining up the source of power with the thresher. During actual threshing, the number of men employed was the same whether the motor or tractor was used : the labour charge is therefore the same for all sources of power. The cost of labour was estimated on a basis of 1s. per hour for the tractor driver and 8d. per hour for general labour.

The cost of electricity for the quarter in which the threshing was done was 1.42d. per kWh : the tariff was 1d. per kWh, the additional 0.42d. representing the quarterly fixed charge spread over a consumption of 3,061 kWh. The price of the petrol used was 1s. 2½d. per gallon, and of the paraffin 6d. per gallon. Lubricating oil, for a consumption of one pint for each experiment, cost 1.9d per hour.

(2) *Overhead Costs.*

The overhead costs are strictly those for maintenance and depreciation : interest on capital invested is actually a charge against profit and not a cost, but it has been included in this report as a cost since the report does not contain a final profit and loss account, where the effect of different capital investments would normally be shown.

To derive the average overheads for each type of plant, some assumptions must be made as to the working life and maintenance costs, items which are more speculative for the electrical equipment than for the tractors.

The farm records show that the old tractor has performed 7,000 hours' work in seven years, and it is considered that this tractor is capable of another 1,000 hours' work at least before it will be scrapped. Consequently, a life of 8,000 hours over eight years has been allowed for the tractors.

The motor, under industrial conditions, might be expected to have a life of at least 20,000 hours, which would correspond to 40 years at 500 hours per annum. The damper conditions on a farm, combined with intermittent use, would result perhaps in a somewhat shorter life.

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Again, the life and maintenance costs of the circuit are as yet not known with certainty.

The following tentative estimates supplied to us from authoritative sources have been used :

Motor.—Life, 20 years ; annual maintenance 2 per cent of original cost.

Circuit.—Life, 25 years ; annual maintenance 2½ per cent of original cost.

Tractor—Annual maintenance figure 3.75 per cent. of original cost.

The depreciation has been calculated from the rate of wear and tear normally allowed for income tax purposes for farming plant and machinery : 22½ per cent for tractors and 7½ per cent for electric motors.

The interest charge is calculated as 5 per cent. of the value of the plant at the beginning of the year.

In calculating the average overhead charges, the total depreciation over the working life (caluclated on the rates of wear and tear previously mentioned), and the total interest charges have been found, and the mean cost per year worked out. (In practice, the depreciation rate allowed for income tax purposes on electrical equipment does not apply to an electrical circuit which is not counted as plant or machinery. For the purposes of these calculations the rate of 7½ per cent. has, however, been assumed to apply.)

The full details of the costings have been given in an interim Report to the Royal Agricultural Society of England, so in the present paper only the summary is given. (Table 4).

Table 4

Charges for one hour's threshing.

(20 h.p. electric motor ; 10-20 h.p. tractor ; each running at half load. Output : 2 tons of grain per hour.)

	Electrical equipment d.	*Tractor* d.
Fuel+oil ; or Electrity	11.4 (8.0 kWh.)	10.1 (Mean for 9 experiments)
Overheads	4.8	9.4
Total	16.2	19.5

This table shows that for the conditions at Rothamsted, electricity is the cheaper form of power. Although the cost of electricity for one hour was 11.4d. as against 10.1d. for paraffin, the overhead charges for the motor are only half those for the tractor.

The cost of electricity was, as stated above, 1.42d. per kW hour. This figure will have to rise above 1.85d. per kW hour before electricity becomes the more costly form of power under the conditions given.

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GRINDING EXPERIMENTS

For a test of medium powered engines and motors a convenient farm operation is the grinding of barley. A Bamford 2C combined grinding and crushing mill is being used, and the two sources of power are :

(1) A General Electric Company 5 h.p. portable farm Drumotor ;

(2) A Bamford 6 b.h.p. portable diesel engine.

The comparisons are less straightforward than for threshing. In the first instance a series of experiments was made, using electric power only, to study the effect of the additional variable factors on the results. These measurements showed that the factors having most influence were changes in quality and moisture content of the barley, the rate of feed to the grinding plates, and the degree of fineness of the ground product.

The first factors can only be made negligible by working with a uniform sample of barley, and uniformity is more easily obtained the smaller the quantity of barley required. The manual controls on the mill make possible a wide range of grinding rate and degree of grinding, but there is no certainty that either of these factors would remain constant for any one setting of the appropriate control, e.g., the feeding rate depends to some extent on the amount of barley in the hopper, on the speed of the mill which governs the reciprocation of the shaker, and may be affected by foreign material in the barley. Any change in the feeding rate would be detected by weighing, at intervals, the output per minute : the degree of grinding, however, can only be judged roughly be feel, and changes could occur which would only be discovered afterwards on completion of a sieving analysis : but even if the fineness of grinding did remain constant during a measurement, the necessity of slackening off the plates before the feed ceases precludes exactly the same setting being used in the succeeding experiment.

These considerations suggest that experiments lasting long enough to provide an accurate overall power measurement were inadvisable, and that it would be desirable to obtain the power requirement for a given grinding rate and degree of fineness over a *short* period of time—of the order of one minute. A number of such observations would then provide the relationship between the three quantities being considered.

In practice the procedure is to alternate the motor and engine in experiments lasting about one hour.

The mill is set to give the required grinding rate which is afterwards maintained approximately constant. Then for one setting of the grinding plates the output per minute and a sample for the sieving analysis is taken : at the same time observations are made

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on the power requirement : the fineness of grinding is then altered and the measurements repeated. This process is continued until a number of observations have been obtained.

Afterwards the other power unit is used for a similar experiment, and the comparison repeated for different grinding rates.

It may be mentioned that the power requirement for the motor is found by timing the meter disc revolutions : for the engine a device is used which enables the fuel consumption to be measured over periods of the order of one minute.

The resulting data thus show, for a series of grinding rates, the variation in electricity and fuel consumptions with fineness of grinding.

This method of working has the advantage that the power units can be compared under identical conditions, and over a range of power output, since from the efficiency curve of the motor the output of the motor can be calculated. The measurements made so far should be regarded as of a preliminary nature. They show that for an output of 5 h.p., for example, the fuel consumption by the diesel engine amounts to 2.30 pints per hour (or an equivalent of 0.49 lb. of fuel per b.h.p. hour). At this output the motor requires an electricity consumption of 4.6 units per hour. Hence 10 kW hours are equivalent to 5.0 pints of the diesel fuel used in our experiments ; account must also be taken of the lubricating oil which, according to manufacturers' directions, will amount to ½ gallon in 100 hours.

CALCULATION OF COSTS (GRINDING)

The same methods of costing described for the threshing experiments have been followed.

The following estimates have been adopted :

Bamford engine—Life 10 years, depreciation 15%, maintenance 5% of £73.

Drumotor—Life 20 years, depreciation 7½%, maintenance 2% of £37 10s.

Circuit—Life 25 years, depreciation 7½%, maintenance 2½% of £5.

The motor engine is assumed to work for 500 hours per annum. Electricity has again been taken as 1.42d. per unit.

The price of diesel fuel per gallon depends on the size of the drums in which it is delivered and ranges, for the oil we have used, from 5½d. per gallon for a 500-gallon drum to 1s. 2½d. per gallon for a 5-gallon drum. The price for a 40-gallon drum, 8¼d. per gallon, has been taken, as this is the most common size for farms. Lubricating oil has been charged at the same price as for the tractor. The summarized figures are given in Table 5.

Table 5

Charges for one hour's grinding.

(6 h.p. diesel ; 5 h.p. drumotor ; each at 5 h.p. output)

	Electrical equipment d.	*Diesel* d.
Fuel+Oil ; or Electricity..	6.55	2.52
Overheads	1.74	5.50
Total	8.29	8.02

This table shows, for our conditions and with the assumptions made above, that the total costs when using a diesel engine are slightly cheaper than those for a drumotor.

Had the cost of electricity been 1.36d. per unit instead of 1.42d., the cost of the two forms of power would have been the same. But in view of the preliminary nature of our experimental results and the somewhat arbitrary assumptions necessarily made in various overhead items of cost, it is fairer to say that at present there seems little to choose between the 6 h.p. diesel and the 5 h.p. electric motor.

Finally it is desired to emphasize one point in connection with the costings results shown in Tables 4 and 5. It will be observed that while electrical equipment has the lesser overheads, it has the higher charges for power consumption.

These two items work in opposite directions. For a small number of hours of work per year, the extra cost of electricity over fuel is not enough to offset the lower overhead charges for the electric motor, and the total cost per hour for the electricity motor is less than for the engine. With increase in the number of hours of work this advantage progressively diminishes and is ultimately reversed.

DISCUSSION

Mr. A. H. Rankin (*Agricultural Development Officer, North Metropolitan Supply Company*) opened the discussion. He said that practically everybody agreed that electricity was the most suitable source of power and light, provided its cost was reasonable. He announced that consumers in the North Metropolitan area could now obtain electricity at the low cost of ½d. per unit provided their heavy demands (e.g., motors and sterilizers) were kept off the peak period. In practice this only amounted to the restriction that they should not be used after 4 p.m. in winter, i.e., after the end of the farm-day, so the restriction was by no means an onerous one, and he anticipated that all dairy farmers within his area would soon have electric sterilizers.

He pointed out that if the new reduced cost per unit were used in place of the figure employed in the paper by Mr. Cashen and Dr. Keen, it would place electricity in a very favourable position,

He asked users in rural areas to realize that the fixed charge. which was sometimes regarded as irksome, was worked out on such a basis as in effect to charge them about 6d. per unit for the current used in lighting—a not unreasonable price. He stressed the need for the proper covering of farm motors which were often left in very wet or dusty places. Protected type motors were often fitted in sites where totally enclosed patterns should be used. He was not particularly attracted by the portable motor, as in his experience most farmers soon place them in a permanent position. He did not think that soil heating by electricity was very practicable ; a more promising development was the circulation of hot water through underground pipes by an electrically driven pump, a method that had been successfully tried at the Hertfordshire Farm Institute, St. Albans.

With regard to the Rothamsted comparisons between the diesel engine and the electric motor the possibility of increased taxes on oil fuel should be borne in mind.

Speaking of Mr. Cameron Brown's paper he felt that farmers must, in the nature of the case, leave a great deal to the wiring contractor. A reputable firm would give a five years' guarantee. Earth leakage devices attached to individual circuits were desirable, but at present they were somewhat expensive.

Mr. J. I. Bernard (*Rural Electrification Officer, British Electrical Development Association*) felt that the best course for a farmer was to put his trust in a reputable contractor who would carry out the farmer's wishes in a competent and reliable form. He recommended earth leakage devices as a valuable safeguard against danger, but he felt that the risk in using electricity on farms had been over-estimated : in industry heavier voltages were handled under even

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more difficult conditions, and with improved equipment mishaps were continually becoming less frequent. Careless use and the neglect of precautions involved danger whatever form of power was used, and there was no justification for regarding electricity as more dangerous than other sources of power.

The ability of an electric motor to stand an appreciable overload for a period without damage or stalling was a great advantage for farm purposes. He felt that the Rothamsted figures of comparative power consumptions were not of general application owing to the difference in working conditions from district to district and even from farm to farm. He wished to know the basis on which various overhead charges had been assessed, since the figure for the ratio of running cost to depreciation in the case of the oil engine seemed to differ from that generally adopted for commercial engines. Another point bearing on the interpretation of the Rothamsted experiments was that the manufacturers of barn machinery tend to over-estimate the horse-power requirements of their machines. Therefore, in his opinion, smaller power units than those recommended could safely be used ; this was particularly the case with the electric motor, in view of its already mentioned capacity to stand an overload for a time.

He thought it was generally accepted that provided the cost of electricity did not exceed 2d. per unit it was well worth while for farm purposes. Any trouble or dissatisfaction was usually attributable to the standing charge ; some farmers do not understand that the cost of transforming the supply and conveying it to the farm has to be met by some means, but difficulties of this kind were not general ; the whole attitude of farmers towards electricity had changed in the last few years.

Mr. H. B. Jenkins (*Bedford Electricity Supply Dept.*) spoke of his experience with farmers in the Bedford area where an early rural electrification scheme had been established. None of these farmers had any electrical knowledge. Operations that formerly needed a skilled man to maintain an internal combustion engine in efficient running condition could now be done by a boy who merely turned a switch. He deprecated fixing lead-covered cables on oak owing to the danger of corrosion. This was no new discovery, for an examination of churches having lead flats or roofs shows that the builders invariably interpose a layer of some other wood (usually pine) between the lead and the oak beams.

Mr. Borlase Matthews (*East Grinstead*) thought the Conference marked the beginning of a new era in the history of electricity in agriculture. The farmer's business was to farm, not to be an engineer. All he needed was a sure source of power and this was unquestionably provided by electricity. At the same time there was needed a comprehensive set of reliable figures on the performance of this new source of farm power in comparison with the older forms ; the Rothamsted experiments were designed to supply such figures.

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He saw no great future for the portable motor, and he recommended that each important machine should have its own motor of the correct size and type and preferably built in as an integral portion of the machine. It was costly and, in his opinion, unnecessary to provide the farm with an installation capable of dealing with the occasional periods of heavy loads, such as threshing time. Portable transformers were now available for this purpose. An electric plough was on the market and was a commercial success ; the cost was only 2s. per acre. Land cultivation by electrically driven machines would greatly increase the agricultural demands for electricity during the off-peak period. Electrically worked pumps were employed for overhead irrigation in a machine known as the "rain cannon." This method was cheaper than the customary one and more closely simulated rain. He stressed the great convenience of electric lighting in the farm buildings, as in addition to easing the stockmen's working conditions it saved them at least half an hour per day. He had made a point of noting every use to which electricity had been applied on the farm ; his list included some 300 different operations. A novel one of these was the erection of cheap temporary stock enclosures consisting of a single strand of wire charged to a suitable low potential. The fence was perfectly stock-tight since directly a beast touched the wire it received a slight shock.

Colonel C. Waley Cohen (*Chichester*) thought it would be a good policy for the supply companies to give the farmer a definite figure for the cost of bringing the supply to his premises. He would then know what the company had to pay and would realize that a certain interest had to be borne on this sum. He thought 20 per cent. for the first year was too high ; a lower figure would lead to an increased use of current. Once electricity is brought to the farm its use should be encouraged in every possible direction and for this purpose the cost should be kept to 1d. per unit as a maximum. He felt that really skilled advice about wiring installations was still rare. Insufficient attention was paid to placing plugs and switches at convenient and safe points, and to designing an installation that would give maximum convenience at once and yet be capable of inexpensive extension when needed. Advice of this nature had saved him £75 on a £175 contract. He was not in favour of giving the wiring contract to the supply company as they often had expensive subsidiary companies for such work ; he preferred the independent contractor.

Mr. J. R. Moffatt (*Farm Manager, Rothamsted*) spoke of the usefulness of the ½ h.p. motor for jobs such as potato sorting and knife grinding. Its convenience was great while its running cost was negligible.

In closing the discussion the *Chairman* dealt with a number of points. The supply companies were always willing to advise a farmer on technical matters. No installation was connected to the supply without a final inspection. Electricity could be a very useful help to the farmer but it must not be expected to accomplish everything. On his own estates, for example, his ploughing costs with paraffin tractors were only 1s. 2½d. per acre, whereas Mr. Borlase Matthews had quoted 2s. per acre for electric ploughing. In this connection he asked that any comparative measurements, such as those now being conducted at Rothamsted, should always be expressed, not in costs per hour, but per acre, or ton of material, as the case might be ; the farmer was interested in the cost of the job, rather than the cost per hour.

In dealing with the cost of electricity per unit he said there were two methods by which the cost could be reduced. Firstly by increasing the off-peak load as much as possible, and secondly by a general increase in consumption. An illustration of the first method was the use of crop drying equipment in summer. With regard to the second point he thought it was not generally realized that the actual production cost of electricity at the generating station was only a small fraction of their total charges. The total cost to the supply company was about 0.9d per unit, and of this amount the actual production cost was represented by only 0.13-0.25d. per unit. The bulk of the charge, therefore, was accounted for by interest, depreciation, and rates. An increase in technical efficiency at the generating stations could not therefore result in an appreciable reduction in the cost per unit to the consumer. On the other hand, an increased use of electricity, especially in the off-peak period would justify an appreciable reduction of the retail price.

The following communication, and replies to the discussion were received after the meeting.

Mr. A. N. D. Kerr (*London*).—There appears to be an impression that because the electric motor is an extremely efficient piece of apparatus, even at light loads, it may be run with impunity underloaded. This is true only of Direct Current motors ; with Alternating Current motors the question of Power Factor must be considered and this item is particularly serious for single phase motors, whose power factor is from 5 to 10 per cent less than that of the equivalent rating three phase machine.

A 20 h.p. 940 r.p.m. Three Phase Slip Ring motor having an efficiency of 87% would consume approximately 17 units an hour on full load and would take about 29 amperes of current on a 400 volt supply assuming the power factor was 86%. The useful current, however, is only 25 amperes : it is this ratio of useful current to current used which is the power factor. Only the useful current is measured on the kilowatt hour meter for the units consumed ; so that where the farmer pays for his current on a flat rate he is only indirectly interested (he is still interested, for though he does not pay any extra for the extra current, he has to provide cables capable of carrying the extra current), but where the farmer buys his current on a two-part tariff, for example, £4 per k.VA of

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maximum demand over a period of, say, twenty minutes plus ¾d. a unit; then though his running charge of ¾d. is unaffected by low power factor, his maximum demand and hence his fixed charge is increased by poor power factor.

In the case of the 20 h.p. S.R. motor, for example, the power factor at half load would be about 75% as compared with about 84% for a 10 h.p. motor operating on full load. In the first case the kVA. input would be 9.95, in the second case 8.9—a difference of approximately 1 kVA. or £4 a year extra by under-running the 20 h.p. motor.

If the farmer has a number of motors installed all underrun the power factor of his installation will be lower and the maximum kVA. demand higher (with consequent higher standing charges) than if he attempts to match his motors more nearly to his loads. In this connection it should be mentioned that the larger motor manufacturers employ trained engineers to advise on the correct application of their motors to the various drives and the services of such engineers are usually available free and without obligation.

It should also be remembered that all electric motors have a substantial overload capacity. All motors above 1 h.p. at 1000 r.p.m. are capable of withstanding 50% overload for 1 minute and 100% for 15 seconds; in addition, motors above 10 h.p. at 1000 r.p.m. will carry 25% overload for 2 hours; between 10 and 4 h.p. at the same speed, 25% for half an hour and from 4 h.p. down to 1 h.p. at 1000 r.p.m., 25% for 15 minutes. Even fractional horsepower motors (those below 1 h.p. at 1000 r.p.m.) will do 25% overload for 5 minutes.

Greater advantage could profitably be taken of this overload capacity, particularly as it is the minimum to which all British motors are built. (Foreign motors are not built to such a stringent specification.)

Now for a word on condensation. All motors need ventilation, primarily to get rid of the heat produced in the windings but also to enable the windings to be kept free from the effects of the humidity in the air. If the motors are totally enclosed—say to prevent injurious dust, grit, dirt or other harmful foreign matter from forming on the windings—then the heat can be dissipated only by radiation from the motor case. This necessitates a larger frame than is possible when the cooling air circulates among the windings. The total enclosure does not, however, render the motors air tight and as a consequence it breathes. When it is running and the windings are hot the internal air pressure is increased and the air driven out through the bearings and other machined surfaces; when the motor is cooled, air is drawn in due to the lower pressure inside, and if the air drawn in is humid—as it usually is—then the water will condense in the windings. It is quite useless to try and minimise the intrusion of such humidity; the best course is to help the water to get out once it is in; and for this purpose small drain holes should be drilled in the base of the motor casing at its lowest point. Any small amount of water which may then get in through such openings will still be able to get out again without collecting in pools at the base of the windings.

In conclusion, farmers are recommended to install squirrel cage induction motors wherever possible. They are low in first cost and, being rugged in construction, are reliable in service ; the only moving parts are metal so that maintenance is a minimum, whilst their performance figures as regards efficiency and power factor are higher than those for the corresponding slip ring machines. The high efficiency means a low running cost, the high power factor a low fixed charge. Finally, their control gear is simple, inexpensive and robust as well.

Mr. F. E. Rowland : Mr. Harvey referred to the misleading figures which are sometimes quoted for the cost of generation with private plant. He stated that in the Electricity Commissioners Report a figure of 1d. per unit for private plant was given but I think he should have emphasised that this was for large commercial plant and not for the small equipment which would be used on farms. For the latter, partly in view of the poor load factor, overhead charges can amount to several pence per unit without taking into account any running costs.

Mr. Cameron Brown's paper was very interesting and a valuable one for discussion at a technical meeting. A lot of the information he gave was hardly required by farmers and may have appeared to make a simple subject appear to be complicated. Farmers should ensure that material of sound quality manufactured by firms of repute, is employed and the work carried out by competent contractors. Price should not be the first consideration for an electrical installation, particularly as there may be only a very small difference between a shoddy installation and a good one. Farmers as a rule do not purchase stock and other requirements solely on price, but consider quality as well, and this practice should be followed with electrical installations.

Mr. Rankin referred to the undesirable practice of some manufacturers fitting protected type motors on machines where totally enclosed should be used. This is undoubtedly so in some instances and is solely due to the fact that price plays such a large part in the sale of most equipment.

Mr. Bernard rightly sounded a note of warning against exaggerating the possible dangers of electricity. When properly installed and used, electricity is perfectly safe and it is only when simple precautions are not taken that danger arises.

Mr. Bernard's opinion that agricultural machinery manufacturers are inclined to quote too high figures for the horse power required by their machines is confirmed by the Rothamsted experience. The 20 h.p. motor which was used for the threshing experiments was supplied to drive the thresher and a chaffcutter, 15 h.p. being allowed for threshing based on the manufacturers figures. From the results it will be observed that a smaller motor would have been satisfactory.

Mr. Borlase Matthews stated that there are now 8,000 farmers using electricity in this country, but did not state on what basis this figure was calculated. 5,000 additional farms were connected last year and it is estimated that the number electrified is in the region of 25,000.

Col. Waley Cohen mentioned that the running charge of two-part tariffs should not be more than 1d per unit. It is desirable that this charge should be kept as low as possible to encourage the maximum use of electricity, although most operations can be carried out economically at a higher figure.

His remarks concerning the desirability of employing electrical contractors rather than supply authorities for installation work does not necessarily apply. The position varies in different parts of the country and a farmer should be able to judge from which firm in either category he should be able to obtain the most satisfactory service. The high cost of leakage trips has been referred to, and it should therefore be recorded that they are now obtainable at prices as low as 11/-.

Mr. Cameron Brown : It is evident from the remarks of Mr. Rankin and Mr. Bernard that the electrical industry is still afraid to be frank with the farmer and to admit that there must be with electricity, as with any other form of power or fuel, a certain amount of danger, but that there are adequate methods of meeting it. It is illogical to suppress this fact, while at the same time expecting the farmer to pay money blindly for special safety devices. A motor car salesman rather boasts about the danger on the roads and how *his* car is well equipped to meet them. Mr. Rankin mentions that these leakage trip switches are not available at competitive prices — competitive with what ? If they are necessary, and it is obvious from an earlier remark that he considers them advisable in many cases, then there is no question of competitive price save with one another—what price can one put on safety ? In any case, a first class trip costing 45/- will protect a 30 h.p. motor both for leakage and overload : can this be considered excessive when the motor and its accessories may cost anything from £40 to £100 ?

Colonel Waley Cohen's remarks on the difficulty experienced by the consumer in getting competent advice on his wiring layout and in finding competent wiremen rather negatives the opinions expressed by Sir Bernard Greenwell and Mr. Rankin that the Supply Companies are looking after that side of the question. Granted that only a good firm would give a five-year guarantee, of what practical use is that when the wiring is expected to have a life of anything up to thirty years. The provision that companies should not supply unless the installation is suitable is compulsory, but I should like to feel that any company does more than it is legally obliged to do in the way of making an insulation test. In any case, this inspection does not take place until *after* the installation is made. It is poor comfort to the farmer to know that he has had a bad installation made and that the company will not supply. He may, it is true, evade paying for this bad wiring but there is bound to be endless trouble and extra expense one way and another. The farmer should, when placing his wiring contract, have a clause binding the contractor to compliance with the Electricity Commissioners' Regulations and to the satisfaction of the supply company.

Mr. Cashen and Dr. Keen : Questions were asked by some speakers on the methods and conventions adopted by us in working out costings. The full details will be found in the Reports submitted to the Research Committee of the Royal Agricultural Society. One point, however, may be dealt with at once—the criticism that the cost of our electricity should have been taken as 1d. per unit and not 1.42d., which is made up of the tariff charge of 1d. per unit and an additional 0.42d. representing the quarterly fixed charge spread over a consumption of 3,061 units. The criticism was based on the argument that the fixed charge for the cost of transformer gear and low pressure line and the minimum use guarantee, are, in effect, a device for recovering from the consumer about 6d. per unit for his lighting (which was stated to be a not unreasonable figure), thus enabling the supply company to provide the consumer's power demands at a much lower figure, approximately 1d. per unit. Although we appreciate the criticism we feel that the method adopted in our paper gives the farmer the more correct position. The inclusive cost for an installation that is to provide both light and power will be greater than one supplying light only ; hence it is reasonable to debit part of the charge to the power consumption. The fixed charge is divided by our method between power and light in the same proportion as the units used for each. If the fixed charge is kept as a separate item in costings data, farmers will have difficulty in arriving at a simple comparison of the *total* relative costs of electricity and other forms of power (and lighting).

It is clear both from the papers and the discussion that the attitude of the farming community towards the fixed charge is, at the best, one of resignation. So long as this is the case, the cheapness of electricity, based on costings comparisons employing 1d. or even ½d. per unit, but excluding the fixed charge, will not completely convince the farmer.

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