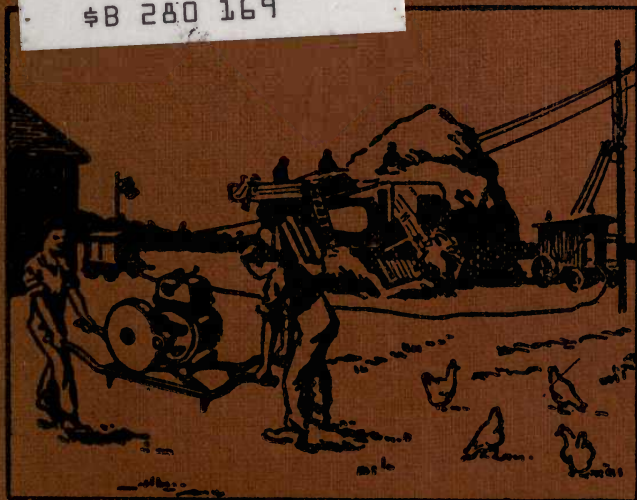


Electricity in Agriculture

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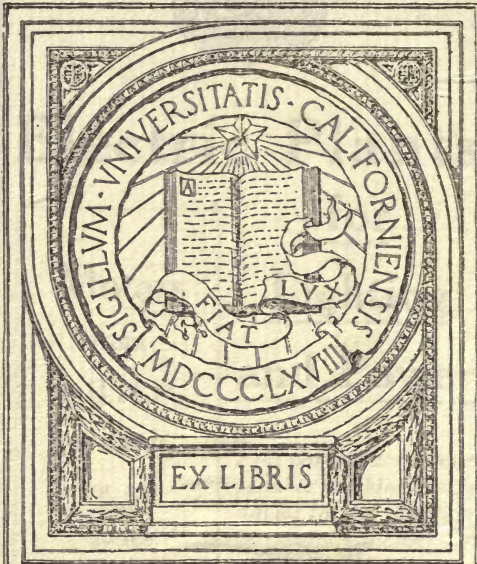


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ELECTRICAL MANUFACTURERS, AND OTHERS

BY

ARTHUR H. ALLEN

MEMBER OF THE INSTITUTION OF ELECTRICAL ENGINEERS



LONDON

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PREFACE

ABROAD, the use of electricity in connection with agricultural operations has attained dimensions of which residents in this country have no conception. Yet there is not the slightest reason why British farmers should not avail themselves of the manifold services which it can render them, even at the present time, whilst in the future—we wish we could say the near future—it is hoped that a supply of electricity will be made available in all parts of the land. In a few places, it is true, thanks to the energy and initiative of the managers of the local electricity supply undertakings, real progress has been made in acquainting the farmer with the possibilities and advantages of electrical methods; but these bright exceptions only emphasize the fact that, as a rule, this very important subject has been neglected by both parties—the farmer and the supply authority.

There is hardly a branch of agriculture in which electricity cannot be employed to advantage; moreover, it immensely adds to the amenities of country life, and should therefore help to stem the flow of population from the country to the town. In these days of dear labour and falling prices, mechanical aids are imperatively necessary to the farmer; and by adopting electricity, he not only fulfils this requirement most efficiently, but also adds very materially to the comfort of his household.

It is the aim of this small book—the first of its kind to be published in this country—to indicate as thoroughly as is possible in the space at command the various kinds of service which electricity can render to the farmer; the methods by which he can at once avail himself of those services; and the value of the farmer, as a desirable consumer, to the supply authority.

In so modest a work it is obviously impossible to deal with any item in great detail; it is hoped, however, that sufficient has been said regarding the various aspects of the subject to interest the reader, and to induce him to investigate the matter more fully.

ARTHUR H. ALLEN.

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SYMBOLS AND ABBREVIATIONS

THE following symbols and abbreviations, adopted by the International Electrotechnical Commission, are used in this volume—

A = ampere	W = watt
mA = milliampere (0.001 A)	kW = kilowatt
V = volt	kWh = kilowatt-hour

For explanation of electrical terms, *see* page 6.

ELECTRICITY IN AGRICULTURE

CHAPTER I

THE APPLICATION OF ELECTRICITY TO FARMING

YEARS ago, agriculture was our chief industry; far-reaching economic changes, fundamentally due to the development of the steam engine and to the industrial revolution brought about thereby, deposed it from that eminence half a century ago—transport was cheapened and accelerated, and the produce of the vast fertile plains of foreign countries was placed on our markets at prices with which our conservative-minded farmers could not compete, though the high quality of their goods enabled them to retain a share of the demand. Thus it came about that in the year 1913, 50 per cent of our total requirements of food was derived from foreign sources. Between 1871 and 1911, 4,000,000 acres of arable land had gone out of cultivation, for it was far more profitable to devote it to grazing cattle, and wages in the agricultural industry, like the profits, were at a very low ebb.

Then came the great war, like a "sharp medicine" indeed, not only calling our stalwart husbandmen from their peaceful occupations to the stern

ordeal of blood and fire, but also threatening to cut off our imported supplies of food and to bring about the downfall of the Empire by sheer starvation of the island Kingdom. That peril was averted, partly by military measures, but also in great part by the feverish activity of our agriculturists, who at the summons of the Government put forth every effort to increase the amount of food produced within our borders. The area of land under the plough was increased by 1,750,000 acres, in spite of the scarcity of labour (in England and Wales there were 200,000 fewer male agricultural labourers in 1918 than in 1913), and it is highly significant that this increase was effected largely by the use of mechanical tractors and other machines operated by mechanical power. The conditions which still obtain, and are likely to continue in operation, compel the British agriculturist to adopt intensive methods of cultivation and to make use of machinery as far as possible, in order to compensate for the high wages and the scarcity of labour which are experienced in all parts of the country.

Mechanical Power Essential in Agriculture.

The future of the agricultural industry in this country depends primarily upon the maintenance, and the continued extension, of the use of machinery for agricultural operations. Failing those conditions, the arable land will inevitably be allowed to revert more and more to pasturage, and we shall eventually be more than ever dependent upon imported food-stuffs—a result which will imperil our national existence in the event of the outbreak of another great war, and which will

be disastrous to our economic welfare even if no such catastrophe overtakes us.

Every effort should be made to popularize and develop the use of mechanical substitutes for manual labour on the land, and it is our object, in the following pages, to explain what electricity can do in this direction, to show how far we lag behind other nations in this respect, and to assist the progressive reader to make good this defect in our national organization.

What Electricity Can Do. Broadly, it may be claimed that every operation which can be carried out with the aid of steam or oil engines can be done as well or better by means of electricity, which also offers many other advantages, such as its use for lighting, heating, and cooking, for transmitting power derived from waterfalls and windmills to the place where it must be utilized, and for the storage of energy in a convenient form.

Mr. R. Borlase Matthews, whose 600-acre farm is electrically operated, states that the cost of producing a given effort on a farm is cheapest by electrical means; oil tractor power costs 2·3 times, horse labour 5 to 6 times, man-power at least 17 times as much as electricity to perform a given task.

When the British Government in 1918 put forward its scheme for the wide extension of electricity supply throughout the whole country, one of the aims on which the greatest stress was laid was the provision of a "cheap and abundant" supply of electricity to farms. That purpose remains in the forefront of the government

programme which is now in course of fulfilment ; a Board of Electricity Commissioners has been appointed, whose prime duty it is to carry the plan into effect, and already vigorous steps are being taken towards that goal. There is, however, no need to wait for the millennium of universal supply ; the advantages of electrical operation can be realized in great part at once.

Possibilities of Electrification. The importance of the subject to electricity supply authorities may be gathered from a statement by Dr. J. F. Crowley in a paper read before the Royal Society of Arts, that in the United Kingdom there are over 428,000 farms of from 5 to 300 acres each, averaging 60 acres, which if electrically operated would require a supply of at least 4,000,000,000 kWh per annum—as much as is generated by the whole of the electricity supply undertakings of England and Wales. Obviously manufacturers of electrical apparatus are equally interested, as there would be an enormous demand for their products.

Official figures issued by the Board of Agriculture show that on 100 acres of cultivated land the British farmer grows only 15 tons of corn and 11 tons of potatoes, as compared with the German farmer's production of 33 tons of corn and 55 tons of potatoes ; the output of meat is about the same in both cases, but the British farmer produces only $17\frac{1}{2}$ tons of milk compared with the German figure of 28 tons. No effort should be spared to increase the efficiency of British farming, and there is no doubt that the use of mechanical power, which has been so widely adopted in

Germany, instead of manual and animal labour, is largely responsible for the difference in the results obtained. That the British farmer is ready—even eager—to adopt electrical methods when they are made available to him has been abundantly demonstrated by the remarkable development of the agricultural load at Hereford, under the enlightened leadership of Mr. W. T. Kerr, until recently the city electrical engineer; and what has been done there can equally well be done at other centres in agricultural districts.

Explanation of Technical Terms. For the benefit of the uninitiated it is necessary to explain briefly the units in which power, energy, etc., are measured. It is important that the definitions and distinctions made in the following paragraphs should be understood clearly, otherwise it is impossible fully to appreciate the data given in subsequent chapters.

“*Work*” and “*Power*.” “*Work*,” in the engineering sense, is a definite entity capable of exact measurement in terms of force and distance, usually pounds weight and feet; thus to hoist a truss of hay weighing 60 lb. to a loft 15 ft. from the ground level would require the expenditure of 60×15 or 900 foot-pounds of work. “*Power*” is the *rate* of doing work, and is measured in terms of work done per minute; thus the same amount of “*work*” is done in lifting the afore-said truss to the loft, whether it is done in one minute or two minutes, but the “*power*” in the former case would be twice as great as in the latter. Power is expressed in terms of “horse-power,” on the assumption that one horse can

lift 1,000 lb. to a height of 33 ft. in one minute ; actually, this is much more than a horse can do continuously. The amount of *power* taken to drive a fully loaded machine is approximately constant, but the amount of *work* it does depends upon the length of time it is in operation ; particulars of the power required to drive various machines used on farms are given on p. 57.

Electrical Units. Electrical quantities may be compared with those met with in water supply ; thus the electrical "pressure" or "voltage" is analogous to the pressure of water in a pipe. Just as water is supplied to consumers at a certain pressure (so many pounds per square inch), so is electricity supplied to consumers at a pressure of so many "volts." For use on farms, this pressure should be 100 or 200 volts, unless the distances are great, in which case a pressure of 500 volts may be necessary. For supply over considerable distances, or for large amounts of power, the pressure may be raised to 2,000 volts or more, but in that case skilled supervision is necessary ; any pressure above 250 volts must be regarded as capable of giving a fatal shock. Electric "current" may be compared with the flow of water in gallons per minute, and is measured in "amperes," representing the rate of flow. A current of electricity supplied at a given pressure represents "power," which may be measured in horse-power ; the amount of power is ascertained by multiplying the current in amperes by the pressure in volts, the result being expressed in "watts." Thus a current of 30 amperes supplied at a pressure of 100 volts equals 3,000 watts. To avoid using these large figures, the electrical

unit of power generally used is 1,000 watts, called "one kilowatt," so that the power above-mentioned is 3 kilowatts. The older unit of power—the horse-power—is rather smaller, being about $\frac{3}{4}$ kilowatt, so that 3 kilowatts equals 4 horse-power. Thus it will be seen that 30 amperes at 100 volts represents 4 horse-power. Similarly 15 amperes at 100 volts represents $1\frac{1}{2}$ kilowatts or 2 horse-power.

Work and Output. The amount of work that can be done with one horse-power depends upon the time during which work is done at that rate, usually reckoned in hours; thus a machine requiring 4 horse-power for 3 hours consumes $3 \times 4 = 12$ horse-power-hours, a quantity of "work" or, as it is often called, "energy." Work or energy can also be measured in foot-pounds; thus one horse-power-hour = $60 \times 33,000 = 1,980,000$ foot-pounds. When electricity is supplied from the mains of a public authority or company, it is measured not in horse-power-hours, but in kilowatt-hours; as explained above, 4 horse-power equals 3 kilowatts, and therefore 4 horse-power-hours equals 3 kilowatt-hours. One kilowatt-hour is the statutory "Board of Trade unit" in terms of which electrical energy is bought and sold. The cost of a kilowatt-hour for driving machinery varies from 1d. to 3d. or more, according to local circumstances; the same amount of energy used for lighting, however, is usually charged for at a higher rate, from 5d. to 10d. or more. One kilowatt-hour will thrash either 14 bushels of oats, 8 bushels of wheat, or 9 bushels of barley, grind 3 bushels of oats, stack 5 tons of hay, cut

$\frac{1}{2}$ ton of chaff, cut up 6 tons of turnips, plough 160 sq. yds. 1 ft. deep, cut and bind a grain crop on $1\frac{1}{2}$ acres, milk 50 cows, or churn 80 lb. of butter, or it will keep 40 lamps each of 20 candle-power alight for an hour.

Abbreviations and Symbols. For convenience it is usual to adopt the following abbreviations and symbols:—

Quantity Measured.	Unit.	Abbreviation or Symbol.	Example.
Electrical pressure	Volt	V	200 volts = 200 V
Electrical current	Ampere	A	10 amperes = 10 A
Power	Horse-power	h.p.	2 horse-power = 2 h.p.
	Watt	W	1,500 watts = 1,500 W
Work	Kilowatt	kW	$1\frac{1}{2}$ kilowatts = $1\frac{1}{2}$ kW
	Foot-pound	ft.-lb.	3 foot-pounds = 3 ft.-lb.
	Horse-power-hour	h.p.-hr.	4 horse-power-hours = 4 h.p.-hr.
	Kilowatt-hour	kWh	3 kilowatt-hours = 3 kWh

These abbreviations and symbols are used henceforward throughout this book.

CHAPTER II

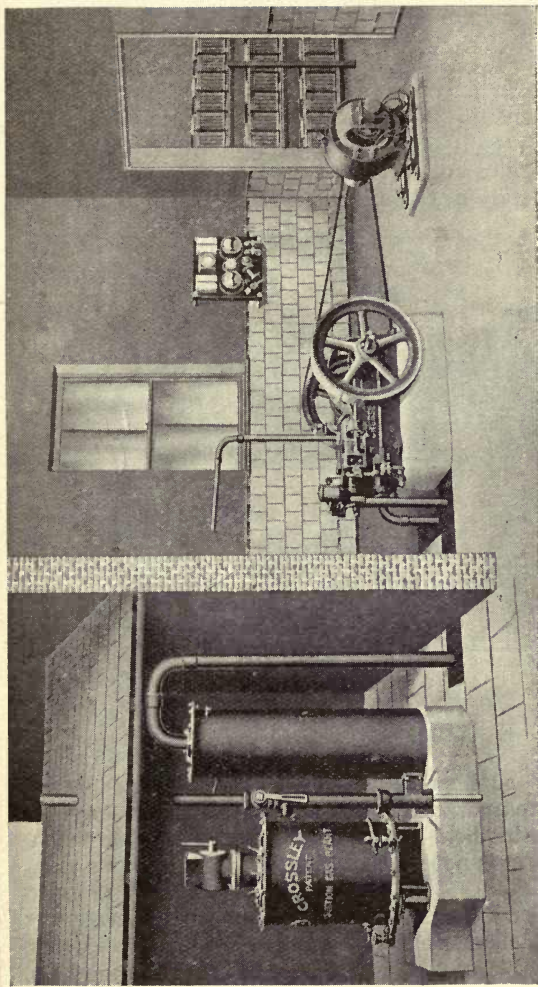
ELECTRICITY SUPPLY

Sources of Power. Where a supply of electricity is not available from an outside source, the farmer must of necessity install his own generating plant, and the question at once arises whence the motive power shall be obtained. The sources of energy at his disposal are coal, oil, petrol, waterfalls, and wind. Of these we may perhaps regard petrol as too costly, though otherwise well adapted for the purpose ; and wind power not only lacks reliability, but is also more expensive than might be supposed. Water-power is by far the most desirable source of energy but, like the wind, is apt to vary widely in strength, and to fail altogether in periods of prolonged drought. Coal and oil are practically free from these drawbacks, and we shall therefore deal with them first. Within the space at our disposal we cannot discuss the subject in great detail, but we will endeavour to indicate the main features of each mode of driving the plant, assuming that the requirements of the farm will be met by a maximum capacity of 10 h.p. This may be provided wholly by running machinery, but it is preferable to employ a reasonable amount of storage, and we shall assume that this course is followed, whereby it becomes possible to reduce the output of the generating plant to, say, 5 h.p.

Power from Coal. Coal may either be used to raise steam in a boiler, or be gasified in a gas producer. There are many objections to the use

of a steam engine, which requires more attention and a higher order of skill than a gas engine, besides being very wasteful of fuel in small sizes ; for these and other reasons it may be dismissed from consideration in this connection. There is less objection to a gas engine and producer of the suction-gas type (*see* Fig. 1), in which the gas is generated automatically in accordance with the requirements of the engine. The plant consists of a gas-producer, a simple apparatus for cleaning the gas, and the gas engine and cooler for the circulating water. Anthracite is generally used, and the producer requires replenishment with fuel at intervals of three or four hours whilst running. Otherwise little attention is necessary, beyond removing the ash and cleaning and oiling the engine. The consumption of anthracite is about $2\frac{1}{2}$ lb. per kWh, costing, at £3 per ton, about 0.8d.

Power from Oil. Simple as is the suction-gas plant, an oil engine is simpler still, and we strongly recommend it as by far the most suitable motor in the absence of reliable water-power. The oil engine, with its cooler, occupies little space and requires but little attention ; it is easily started, and can be left running all day unattended. It is a highly economical prime mover, consuming about $\frac{3}{4}$ lb. of oil per kWh, and the fuel, which is supplied in drums or barrels, is clean and easily handled compared with coal. The fire risk is negligible, if the exhaust pipe is kept away from combustible materials, and the oil is stored below ground or in a safe place at a distance from stacks or barns. Very little water is required to

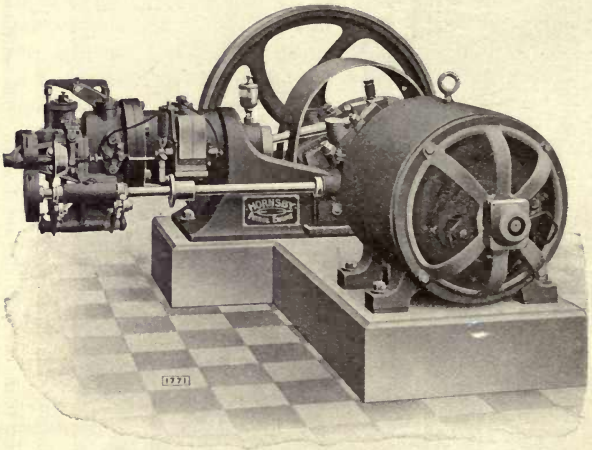


Crossley Bros., Ltd.

FIG. 1.—SUCTION-GAS ELECTRIC GENERATING PLANT. 3½ kw.

The gas producer (left) supplies gas to the engine driving the dynamo. The switchboard on the wall controls the electrical supply. Part of the storage battery is visible through the door at the right of the illustration.

fill up the cooling tank. The engine should be bolted to a concrete foundation, and may drive the dynamo by belt, but is frequently coupled directly to it on a common bedplate (see Fig. 2). Oil engines are so widely used nowadays for farming operations that there is no difficulty in obtaining



Ruston & Hornsby, Ltd.

FIG. 2.—OIL-ELECTRIC GENERATING PLANT. $2\frac{1}{4}$ kw.

labour sufficiently skilled to look after them. As a temporary expedient, the dynamo may be driven by belt from an oil-engined tractor when the latter is not required for its customary purpose.

Water-Power. Where water-power is available in sufficient volume and can be developed at reasonable cost, it is the best of all prime movers,

as it consumes no fuel, and a water turbine can be left running continuously, day and night, without attention other than occasional oiling. The considerations which determine whether adequate water-power is available are the flow of water in cubic feet per second, the available height of fall, and the regularity of the flow. The distance of the fall from the farm is not of much consequence, provided that permission can be obtained to use the power, and wayleaves to carry the mains across the intervening property—unfortunately, these often prove to be insuperable obstacles to the utilization of water-power.

Whether a waterfall is capable of development at a reasonable cost is a question which can only be decided by an engineer after an inspection of the site; but in order to ascertain whether there is any likelihood of its being usable, the following rough rule may be applied by anyone: multiply the head of water in feet by the volume of flow in cubic feet per second, and divide the product by 12. The result is approximately the brake horsepower available. The flow of water should be measured, together with the head or difference of levels, at various periods of the year, particularly the season when the stream is at its lowest.*

In order to "harness" the fall, it will usually be necessary to build a dam across the stream, and this should be so disposed as to pond back the water, thus obtaining a certain amount of

* For further information on the estimation of water-power possibilities and on methods of utilizing water-power, the reader should refer to *Hydro-Electric Development*, by J. W. Meares, uniform with this volume (Pitman, 2s. 6d. net).



FIG. 3.—WEIR ON SMALL STREAM FOR HYDRO-ELECTRIC PLANT.



FIG. 4.—PIPE LINE FROM WEIR TO TURBINE HOUSE.

storage (*see* Fig. 3). From the dam the water is led in pipes (Fig. 4) to the turbine-house, situated at a lower level, and there actuates the turbine. The latter drives the dynamo either by belt or by toothed gearing.

Wind-Power. Wind-power is commonly used for driving small pumps by means of a wind-rose or turbine, but is much less widely used for generating electricity than it well might be. It is true that the wind is capricious—far more so than even water-power, which also is largely dependent upon the weather—but nevertheless, with the aid of storage, its fickleness can be neutralized to a great extent, and an occasional shortage of wind-power, involving the postponement of mechanical operations, is not necessarily disastrous. In this country the average velocity of the wind throughout the year is in the neighbourhood of $7\frac{1}{2}$ miles per hour, but during two-thirds of the year it exceeds 10 miles per hour, which is well above the lowest speed at which it will drive a wind motor satisfactorily. For about one-third of the year the velocity approaches 15 miles per hour, and in favourable situations this may be much exceeded. The average velocity is lowest in summer, when the demand for lighting is also least, and many mechanical operations on the farm, such as thrashing, grinding, cider-pressing, etc., are suspended.

The windmill (*see* Fig. 5) is mounted on a light steel tower, usually 50 to 70 ft. high, or on a hill top, and is provided with automatic governing devices to accommodate its aspect to the strength of the wind; if properly constructed, it only

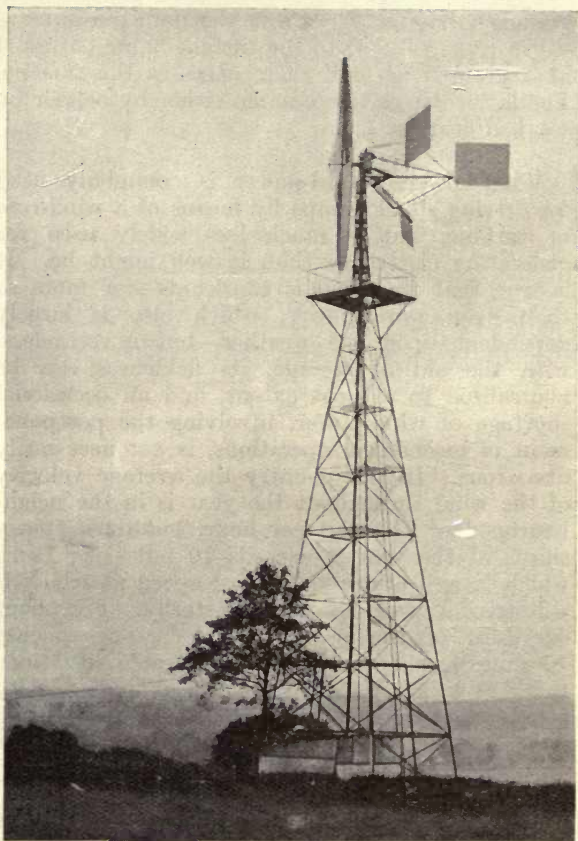


FIG. 5.—WIND TURBINE FOR DRIVING ELECTRIC PLANT.

needs an occasional visit for lubrication, and the cost of repairs is trivial. Owing to the very variable speed of the wind, a special type of self-regulating dynamo is used to charge the storage battery. The cost of a complete installation before the war was estimated at £450, covering the wind motor and tower, dynamo, switchboard, battery and building. Under present conditions (1922) the cost would probably be £1,000. The dynamo would give a maximum, with a strong wind, of 4 h.p., and the battery would give an equal amount of power for 8 hours; as the battery could give a greater output for a shorter period, up to about 15 h.p. for 1 hour, ample power would usually be available for all ordinary farming operations, even during periods of calm.

Storage of Electricity. Emphasis may here be laid upon the feature which is common to all uses of electricity, viz., the fact that it can be stored conveniently in stationary apparatus for use at a future period. This makes it possible to obtain from a stream which is capable of giving only, say, 2 h.p. continuously, an enormously increased output at command for short periods. Such a stream would by charging a battery continuously day and night, afford a supply of about 20 kWh daily, which would drive a 5 h.p. machine for some 4 hours at full load, and would cover most of the requirements on a small farm. A similar argument applies to the use of wind-power; although the power generated varies from moment to moment, no inconvenience is experienced, as the energy is stored in the battery, whence it may be drawn at any time and at any desired rate,

and the plant can be left running continuously, under the control of automatic regulating devices. In the case of wind-power there is no question as

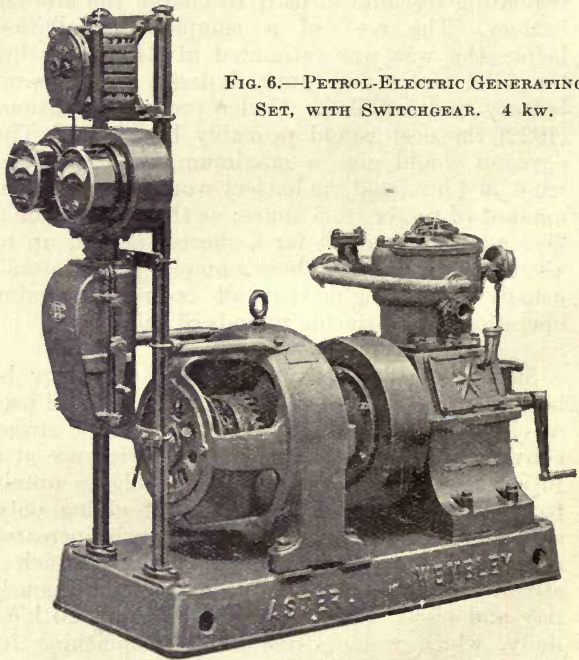


FIG. 6.—PETROL-ELECTRIC GENERATING SET, WITH SWITCHGEAR. 4 kw.

Aster Engineering Co. (1913), Ltd.

to wayleaves, or water rights, and the capital cost can be ascertained precisely beforehand, whereas in the case of water-power the cost of the dam is somewhat uncertain.

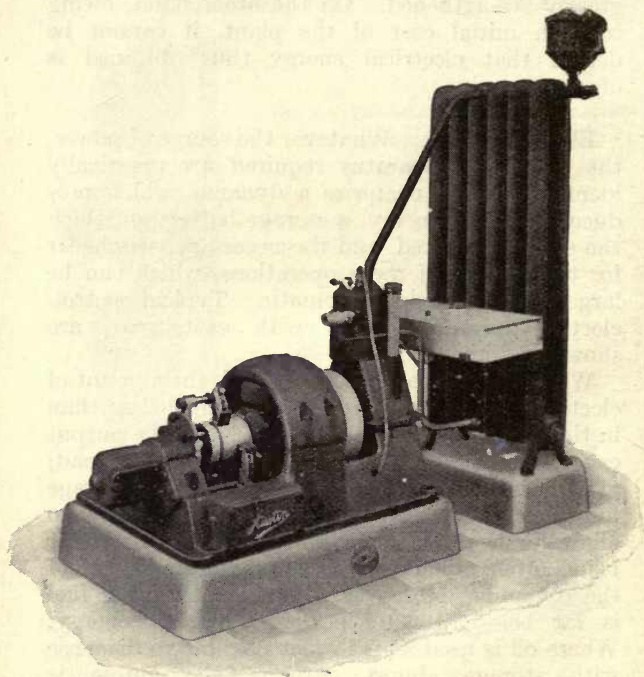
In view of the high cost of fuel nowadays and the

need of economy in its use, the arguments in favour of the adoption of either water- or wind-power are greatly strengthened. On the other hand, owing to high initial cost of the plant, it cannot be denied that electrical energy thus obtained is often expensive.

Electrical Plant. Whatever the source of power, the electrical apparatus required are practically identical. They comprise a dynamo, which produces electrical energy, a storage battery in which the energy is stored, and the necessary switchgear for the control of these operations, which can be largely or entirely automatic. Typical petrol-electric generating sets, with switchgear, are shown in Figs. 6 and 7.

When the source of energy is fuel, the amount of electrical storage required is very much less than in the case of water- or wind-power, as the output can be adjusted to the demand (up to full load) at will where fuel is used, whereas additional storage for wind or water-power plant is necessary to allow for the maximum power of wind or water being often much below the maximum power of the dynamo. Moreover, the cost of storing fuel is far below that of storing electrical energy. Where oil is used, it is in fact possible to dispense with storage almost entirely, the automatic control (Fig. 7) causing the engine and dynamo to start the moment any consuming device, from a glow lamp upwards, is switched on. It is highly advisable, however, to employ sufficient storage to carry on the lighting and other indispensable functions for at least three days, to provide against a temporary stoppage of the engine or

other item of the plant. The installation should be housed in a dry and well-ventilated building

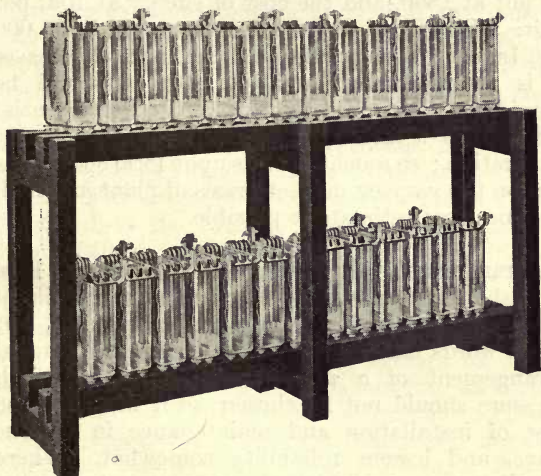


Austin Motor Co., Ltd.

FIG. 7.—AUTOMATIC PETROL-ELECTRIC GENERATING SET. $\frac{3}{4}$ kw.

away from dust, and from manure heaps; the latter give off ammoniacal vapours, which are highly injurious to storage batteries. The storage

cells may conveniently be carried in two tiers by a wooden stand resting on a brick floor (see Fig. 8).



Pritchett and Gold and E.P.S. Co., Ltd.

FIG. 8.—ELECTRIC STORAGE BATTERY FOR FARMHOUSE.

Cost of Plant and of Energy Produced. The cost of a complete self-starting oil-engine-driven outfit of 5 h.p. is £375 at the time of writing. Allowing for attendance, interest and depreciation, repairs and stores, and assuming a consumption of 4,000 kWh per annum, the cost of energy obtained by this means may be estimated at 6d. per unit. The cost of a suction-gas plant to give equivalent service would be about £300, and the cost per unit about 6d. In each case allowance is made for only a small amount of

storage. The cost of a water-power installation, assuming that the hydraulic works are of a simple character and the pipe line not unduly long, may be put at £800, and the cost of energy at 10d. per unit. With wind-power the costs would be £1,000 and 1s. per unit respectively. In the last two cases it is assumed that sufficient storage would be provided to maintain lighting and other essential services for a fortnight. These prices are merely illustrative ; so much depends upon local conditions and on the varying market prices of plant and fuel, that no close estimate is possible.

Arrangement of Plant. In the space here available it is impossible to discuss the details of the generating and storage plant more fully, but a few words may be added concerning the general arrangement of a private installation. A high pressure should not be chosen, as it increases the cost of installation and maintenance in various ways, and lessens reliability somewhat. Where the distance over which the current is to be distributed does not exceed, say, 100 yards, a pressure of 100 V is quite high enough. No higher pressure need be used unless the working and lighting places are widely scattered, or the loads exceptionally heavy. A pressure of 200 V may be regarded as the highest ever required for general distribution for lighting, heating, and cooking, and for power up to 10 h.p., but the lower voltage is preferable.

Where practicable, the engine-room should be near the house for convenience of access in bad weather, but not so near as to cause a nuisance by noise and exhaust fumes. Where water or wind-power is employed, it may not be possible to site

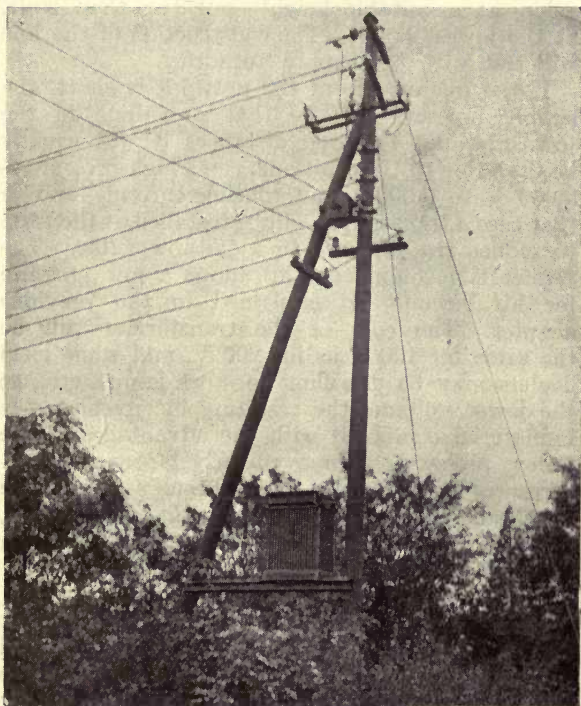
the dynamo-room close at hand, but the storage battery should be near the house if possible, in order to keep it under observation and to secure the best regulation of the lights. Every cell of the battery should be examined once a week, and any indications of irregularity should be at once followed by steps to remove the trouble. While storage batteries nowadays are very well-made, they remain the weakest point of the installation. One important advantage of a low voltage is that the number of cells required is correspondingly low—33 for a 100-V system. One person ought to be instructed in the care of the plant, particularly of the battery, and should be held responsible for its maintenance in good condition.

Capabilities of Electric Plant. Even a very small plant will do a surprising amount of work. On the farm of Mr. W. W. Ballantyne, at Stratford, Ontario, a $\frac{3}{4}$ kW set runs a milking machine, a cream separator, a pump in the dairy, a root-pulper, an emery wheel, horse clippers, a sheep-shearing machine, a fanning mill, a washing machine, a suction cleaner, an electric iron, and a toaster, besides charging batteries for motor-car lighting, pumping water for the house, and lighting the farm-house and out-buildings. Naturally these devices are used at various times during the 24 hours and not simultaneously. The owner finds that he can dispense with the labour of one man, besides enjoying the convenience of electric lighting, etc. (*Electrical News*, June 1st, 1920.)

A large number of firms, both British and foreign, are manufacturing small oil-engine and dynamo

sets, from $\frac{3}{4}$ kW upwards, for private installations. In some cases these are to a great extent automatic, the engine and dynamo starting up when the battery requires charging.

Public Supply. It is hoped that at no distant date, a supply of electricity will be available at all parts of the kingdom near a town or a railway. Where such a supply can be had, the farmer will be well advised to use it, as he will thereby save himself the outlay of capital on private plant, and will avoid all risk of a prolonged failure of the supply, besides obtaining energy at a lower price than that of production by private generating plant. Application should be made to the supply authority concerned, who will state the terms on which a connection can be made. As a rule, farms are not likely to be situated near the route of existing mains, and therefore special mains must be laid to supply them; it will then be found highly advantageous, if not indispensable, to co-operate with neighbouring farms in obtaining a supply of electricity, as each will secure lower terms, and the mains will be laid in the most suitable direction. The cables may be either underground or overhead; for short distances the former will be preferred, where an underground network is already laid, but for distances exceeding, say, half a mile, or where the township is supplied through overhead cables, the latter should be employed. The poles are usually erected in the hedge-rows (Fig. 9) to avoid obstruction to farming operations, and to ensure accessibility to them without damage to crops, but the overhead cables can be carried across corners of



By courtesy of Mr. W. T. Kerr.

FIG. 9.—TRANSFORMER POLE IN AGRICULTURAL SUPPLY SERVICE.

Showing incoming high-pressure line, isolating switches, 10 kVa transformer, low-pressure switch and fuses, and outgoing low-pressure 3-phase, 4-wire distribution.

fields, at a suitable height—not less than 20 ft. at the lowest point. The construction of the line will rest with the supply authority.

If the distance from the network is short, the supply pressure will be that prevailing in the township, but for long distances it will usually be desirable to transmit energy at high pressure—2,000 V to 5,000 V, alternating current—and in that case a transformer will be installed at the farm to reduce the pressure to a suitable value. The farmer is recommended to adopt a low pressure for his circuits, as explained in the previous chapter. The cost of the transformer will be the same for 100 V as for 200 V, and while local dealers may be unwilling to stock lamps, etc., at the lower voltage, the resulting inconvenience is immaterial compared with the advantages of the lower pressure. Moreover, when several low-pressure installations have been started, the agents will waive their objection; and at the worst, supplies could always be obtained directly from the makers.

Alternating Current Supply. Having a constant supply of electricity available, the farmer will not require storage. As a matter of fact, the supply in thinly populated areas will almost invariably be given by alternating current, which is not suitable for storage without conversion. The advantages of using alternating current are very material; not only can its pressure be changed by a transformer to any desired value, at small cost, but also the motors used with it are exceedingly simple and robust, and the controlling gear is reduced to the minimum. Thus an

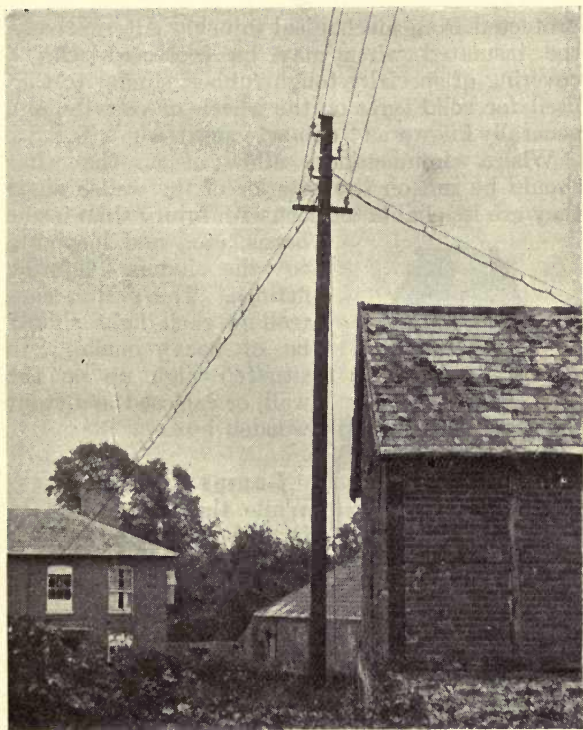
alternating current motor can be put in the charge of an unskilled man without risk of injury, and the drive is effected in the simplest possible way. Moreover, if the farmer wishes to adopt electric ploughing, cultivation, etc., alternating current is far more flexible than direct current, and indeed is almost indispensable. The only advantage of direct current, perhaps, is the facility with which electric battery vehicles can be charged on the premises where it is used ; but this is not a serious matter.

CHAPTER III

THE DISTRIBUTION OF ELECTRICITY

The Distributing System. The supply authority's mains—and statutory powers—end at the consumer's terminals, to which the incoming cables are brought after passing through a double-pole switch and fuses belonging to the supplier, and a meter. Beyond that point the farmer has complete control, subject only to the requirement of law that he shall not use his supply in such a way as to interfere with the supply to other consumers. The uses of electricity for lighting and for other applications in the house are discussed in Chapter IV; it only remains here to consider how to bring the electric current to the lamps and motors in barns and outhouses. Properly handled, electricity is the most flexible means of distributing power in existence; improperly handled, it may give rise to quite unnecessary troubles.

Wiring Systems. For lighting purposes, a permanent system of wiring to the various points will be necessary. The accepted method for a high-class job is to enclose the insulated wires everywhere in screwed steel tubing, but this is not at all essential. Cheaper tubing systems are available, as well as systems in which the insulated wires themselves are enclosed within a continuous metallic sheath, and for most purposes, at moderate voltages, such sheathed wires are perfectly suitable, besides being easy to install, and adequately



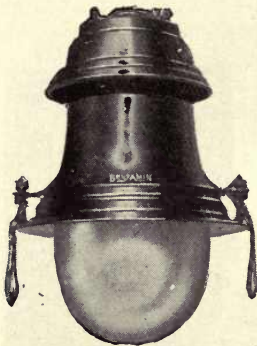
By courtesy of Mr. W. T. Kerr.

**FIG. 10.—LOW-PRESSURE SUPPLY LINES ENTERING
FARM.**

Single-phase supply is taken to the house and 3-phase supply to the farm buildings

protected from mechanical injury. Alternatively, the insulated wires may be protected with a covering of specially tough rubber, similar to that used for solid tyres on the wheels of vehicles, and generally known as "cab-tyre sheathing" (C.T.S.).

Where circumstances allow of it, the wires should be run on the exterior of the walls, where they are less liable to meet with injury than inside barns, etc., and looped-in to the indoor lighting fittings. The switch controlling each light should be of heavy make, and situated high up on the wall, or enclosed in a stout wooden box.



Benjamin Electric Co.

FIG. 11.—ELECTRIC LAMP FITTING FOR FARMYARD.

Lamps and Fittings.

While the lamps used in farm buildings and yards are identical with those used in the house—with the exception that for lighting large spaces the "gasfilled" type of lamp is preferable to the ordinary "vacuum" type, on account of its greater economy—the fittings are wholly different. Lamps in working places or in the open air should be protected by fittings with stout glass covers, and provided with suitable reflectors (*see* Fig. 11). In very exposed positions further protection should be provided by metal guards outside the glass covers. The fittings should be of very substantial construction, waterproof if out of doors, and of suitable material.

Ordinary fittings, if exposed to ammoniacal vapours, are quickly corroded and destroyed.

An electric lamp is practically devoid of fire risk, under normal conditions. Even if the bulb is broken, the lamp cannot set fire to anything, for the filament is destroyed instantly and thus the current is cut off. The only case in which fire risk is present is when the bulb is in close contact with inflammable material for a long period whilst burning. The heat being then unable to escape freely, the temperature may rise to ignition point. Hence it is important to place the lamps where the air can circulate freely, and there is no possibility of hay, etc., being piled up so as to bury them.

Ease of Control. One of the conveniences of electric light is the facility with which it can be controlled. It is easy, for instance, to arrange switches at each end of a long cattle shed, so that a person entering at one end can switch on the lights, pass through, and turn them out as he leaves at the other end, without retracing his steps. Yards can be lighted brightly with lamps mounted on poles or on the walls of buildings, and a switch can be provided in the farmer's bedroom, so that if he hears suspicious noises in the night, he can flood the yards with light, without leaving his room.



Benjamin Electric Co.

FIG. 12.—PORTABLE
ELECTRIC LAMP.

Portable lamps are also of the greatest utility to the farmer. The bulbs are mounted in strong lanterns (*see* Fig. 12), connected by flexible cable of any desired length with plugs which can be inserted in wall-sockets permanently fixed at suitable points. Thus the user can carry a lantern from one building to another, obtaining light with which he can inspect the remotest corners, without the least risk of setting fire to hay or other combustible materials.

The ability to carry on work in barns, etc. after darkness sets in, where other lights could not be used with safety, is one of the many advantages conferred upon the farmer by the use of electricity.

Power Wiring. The wiring for fixed motors can be carried out in the same manner as for lighting. Where the supply is single-phase alternating current and is given through a double-wound transformer, the amount of insulated wire required may approximately be halved by using "earthed concentric wiring." This consists of an insulated conductor covered by a bare metal sheathing which is used to carry the return current. This system is mentioned on account of the economy in wiring which it makes possible; the system is not, however, universally permissible and it should be adopted and installed only under the supervision of a competent electrical engineer.*

* This remark applies to the whole of the electrical installation. The farmer should never himself attempt to install or extend electrical equipment. It costs little more to obtain professional advice and skilled labour at the time of installation, and by this means it can be ensured that the whole equipment can subsequently be used safely and efficiently by unskilled labour.

For supply to portable electric motors, wall sockets should be provided at suitable points within 20 ft. of where the motor will stand, the wiring thus far being of the class used for lighting. Each motor will be provided with a length of flexible cable and a plug corresponding to the sockets, so that it can readily be plugged in anywhere. Each such wall-socket must be fed through a switch capable of breaking the current taken by the motor at full load, and should be in a situation protected from the weather.

Overhead Lines. In some cases it will be desirable to use portable motors in the fields, away from the buildings; it will also be necessary to cross spaces between buildings. In such cases it is preferable to carry the wires overhead, where they will be out of reach of mechanical damage and corrosion by seepage from manure heaps or drains. The height must be chosen to clear fully-loaded carts of hay, etc., by at least the height of a man erect—say, 20 ft. from the ground to the lowest point of the wire, poles being erected if necessary to attain that elevation.

The conductors may be of bare stranded cable, of copper or aluminium. The cables are bound to insulators supported by swan-neck brackets, screwed into the poles, and may be connected to the indoor wires by running the latter up the terminal pole (in an iron pipe, if exposed to damage), and clamping them securely to the cables.

The terminal pole in the field should be provided with a stout wooden box containing the socket,

and having a lock-up door. By carrying the bare cables on a line of poles along the side of any field, it is made easy to tap them anywhere by means of conductors attached to metal hooks and provided with a handle, as described below.

Tapping High-Pressure Mains. While it is undesirable to employ high pressures on power lines used for agricultural purposes, circumstances may render it necessary to do so, and on the Continent the practice is not uncommon. In such cases the ordinary plug and socket method of connection cannot be used. Special connecting devices are mounted on some of the poles which carry the high-pressure mains. These devices may consist either of a set of copper hooks mounted on insulators at a height of about 20 ft. from the ground, and connected by cables to the line conductors, or special sockets, one for each line conductor. Alternatively, the connection may be made directly to the line conductors by means of special tapping devices.

Fig 13 shows a switch for mounting on the pole where a tapping is to be effected, at a height of 15 or 20 ft. from the ground. The switch-rod *S* has an extension at the lower end so arranged that the flexible conductor *C* (leading to the transformer truck mentioned later) cannot be put on the hook *A* until the switch has been placed in the open position, as illustrated; in this position, the switch isolates the hook from the line, so that the cable can be attached in perfect safety by means of a long pole. The switch-rod *S* is then pushed into the contact *B*, which is connected with the line conductor by a cable *L*, and

locks the ring on the hook *A* by the same movement.

Fig 14 shows a tapping pole provided with a hook *H* at the upper end, which can be hooked on

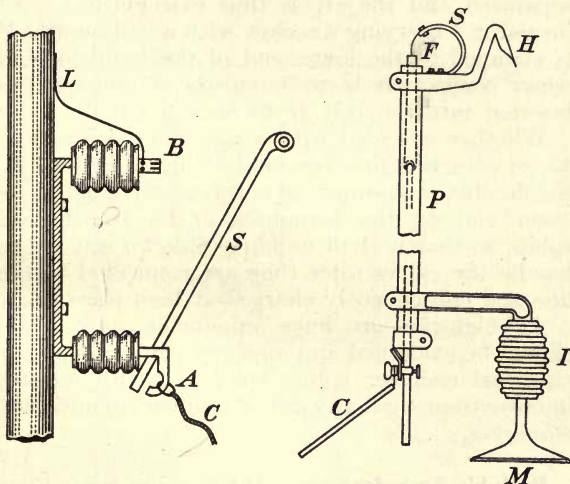


FIG. 13.

POLE SWITCH CONTROLLING
CONNECTION BETWEEN
OVERHEAD LINE AND
FLEXIBLE CABLE.

FIG. 14.—IMPLEMENT FOR
MAKING CONNECTION WITH
BARE WIRES.

Connection is made between the hook (which rests on the overhead wire) and the terminal (to which the flexible cable is connected) by a conductor running through the centre of an insulating rod. The implement is manipulated by a pole inserted in the insulated socket *M*.

the actual line conductor ; a spring *S* attached to the hook is connected by a fuse-wire *F* to a rod passing through the bamboo pole *P*, the lower end of the rod carrying a terminal to which the flexible

cable *C* is clamped. When the rod is drawn down into the position shown, the fuse wire is tightened by the spring, so that if an excessive current passes and melts the fuse-wire, the ends are rapidly separated and the arc is thus extinguished. An insulator *I* carrying a socket with a bell-mouth *M* is clamped to the lower end of the bamboo, and when connection is to be made, a long pole is inserted into the bell *M* to form a handle.

Whether provided with a ring as shown in Fig. 13, or attached to a terminal fitting as in Fig. 14, the flexible cable must be permanently fixed at its other end to the terminals in the transformer cabin, so that it shall be impossible for anyone to handle the cables after they are connected to the line and consequently charged at high pressure.

All high-pressure lines, apparatus, and cables should be examined and approved by a competent electrical engineer before being put into service, in order to prevent any risk of accident to unskilled employés.

Portable Transformers. When a pressure above 500 V is employed, it is necessary to transform it to a lower value for use on the motors. The best practice is to house the transformer permanently in a weatherproof hut or building, but in the United States and Canada the transformer itself is often made weatherproof and fixed in the open, or, if of small size, on one of the line poles, the general appearance being then as in Fig. 9. This eliminates the making of temporary connections to the high-pressure lines, but a transformer must be provided at each point from which it is wished to take supply. Capital expenditure is reduced

and greater flexibility of service is obtained by arranging to make temporary connection to the high-pressure line at any desired point. A portable transformer is then required, mounted in a

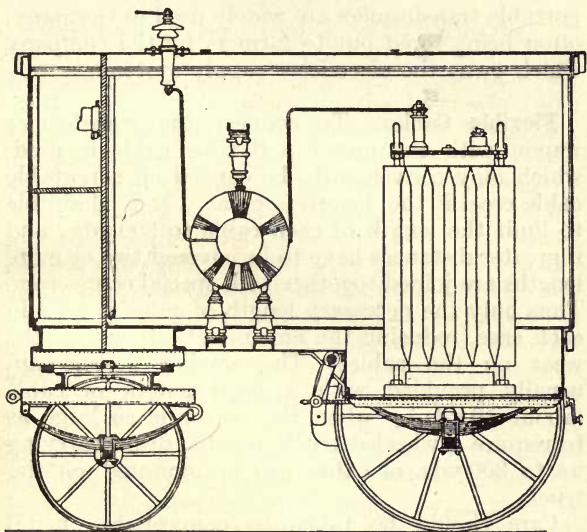


FIG. 15.—SECTIONAL ELEVATION OF TRANSFORMER TRUCK FOR AGRICULTURAL SERVICE.

Showing 90-kVa oil-cooled transformer, reactance coil, and compartment for switchgear.

covered wagon provided with broad wheels and arranged for haulage by horses or by tractor. A transformer truck for 70 kW weighs about three tons complete, and can be hauled by two horses. The interior of the wagon is divided by a partition into two compartments, one containing the transformer

and the fuses necessary for its protection, together with a "choking coil" to prevent damage by lightning, whilst the other contains the low-pressure switchgear and a cable connecting box.—Such a wagon is shown in section in Fig. 15. These portable transformers are widely used in Germany, often being hired out to farmers by the company which owns the electricity supply system.

Flexible Cables. To connect the transformer wagon with the motor a flexible cable is used, which may conveniently be carried on a portable cable creel if the length is great. It is desirable to limit the length of each cable to 300 yds., and if greater distances have to be covered two or more lengths are joined together with special connectors. Thus only the necessary length of cable is used in each case, reducing the amount of labour and the wear on the cables. The smaller motors are usually provided with a short length of cable (about 10 yds.); when the motor is so large as to require a wheeled truck, a cable drum carrying up to 300 yds. of cable can be mounted on the truck.

Care should be taken to connect the metal framework of the transformer wagon with the earth when it is in use, by means of a cable connected to an iron rod driven deeply into damp ground.

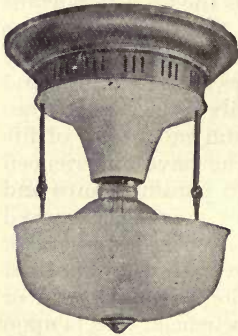
CHAPTER IV

DOMESTIC APPLICATIONS OF ELECTRICITY

Indoor Lighting. By no means the least important of the uses of electricity on the farm are those which are centred in the homestead. Electricity can contribute in so many ways to the comfort and well-being of the family that its introduction goes far to mitigate the isolation and monotony of life in a country house. Those who have experienced the discomforts of lighting with paraffin lamps and candles during the long winter evenings, relieved by little in the way of public entertainments or other distractions, can appreciate the contrast afforded by brilliant illumination without odour or eye-strain, with the resultant beneficial effects upon health and humour. Lighting is naturally the first consideration following upon the provision of a supply of electricity, and it should be carried out in accordance with scientific principles, in order to secure all the advantages of electrical methods without introducing undesirable effects. Owing to the brilliancy of the incandescent filament, no lamp should be directly visible to the eye, the pupil of which, if exposed to a bright light, immediately contracts and thus largely neutralizes the benefits of ample illumination; in fact, a room in which there is a bright unshaded light is essentially a badly lighted room, and will always appear as such.

Electric light lends itself like no other illuminant

to control by suitable shades and reflectors, and to waste this quality would be foolish. The most pleasing method of using it is that known as semi-indirect lighting, in which the lamp is suspended in a translucent bowl (Fig. 16), fairly near the white ceiling; part of the light passes through the substance of the bowl, shedding a soft illumination



*British Thomson-Houston
Co., Ltd.*

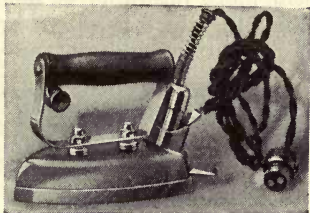
FIG. 16.—BOWL FITTING
FOR ELECTRIC LAMP.
SEMI-INDIRECT LIGHTING
SYSTEM.

on the walls and tables, whilst part is thrown directly on the ceiling and diffusively reflected therefrom, the resultant effect being ideally cheerful and pleasant. Where electric light is used, a ceiling remains white for years without requiring renewal, and the walls and curtains also keep clean far longer than with any other artificial illuminant. Where a strong light is desired, as upon a library table, suitable reflectors are available which, without permitting "glare," concentrate the

light in the required direction without plunging the rest of the room in darkness. On the other hand, where a subdued light is needed, as in a bedroom where there is a young child, the light can be reduced to any desired degree by a dimming switch. To secure all these advantages to the full, it is advisable to employ a competent contractor. If the supply pressure is 50 V or 100 V, the range of sizes of lamp available is greater than with higher pressures; more efficient lamps are also

obtainable for the lower pressures. These are important reasons for choosing a low voltage. As the house will in most cases be built before the electric light is introduced, a system of wiring should be chosen which can be carried out without undue interference with the walls and decorations.

Such a system is the metal-sheathed or rubber-covered wire already described in connection with the lighting of the farm buildings, which can be installed neatly and unobtrusively, as well as quickly, and at moderate expense.



Falkirk Iron Co.

FIG. 17.—“FALCO” ELECTRIC IRON.

Much depends upon the proper choice of positions for the lamps, and this also should be the subject of competent advice; the ordinary householder should realize that experience and skill are essential to the attainment of the best effects.

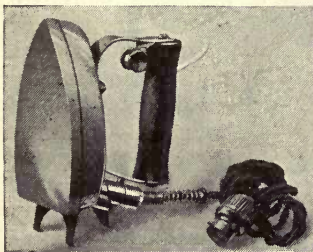
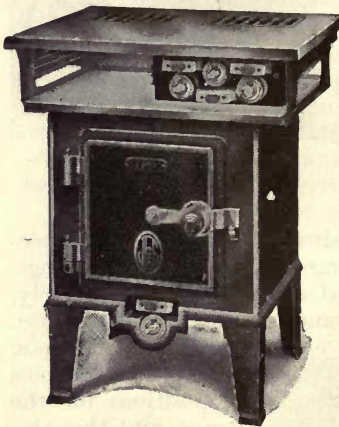


FIG. 18.—“FALCO” ELECTRIC IRON, SHOWING HEEL REST IN USE.

Electric Irons and Cooking. There are many other directions in which electricity can lighten domestic duties and add to the amenities of the home. For instance, the electric iron (Figs. 17

and 18) is a boon to the housewife, which, once she has tried it, she will never willingly forgo. Still more desirable is the electric cooking stove (Fig. 19), which has been brought to a high degree of perfection, and not only simplifies the art of



Jackson Electric Stove Co.

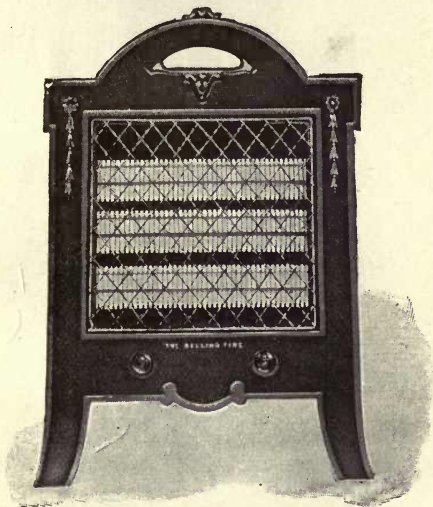
FIG. 19.—ELECTRIC COOKER
FOR SIX PERSONS.

The switches shown provide separate heat control for the boiling plates, grill and oven.

cookery, but also effects an enormous economy of labour and abolishes the huge coal fire necessary to heat the old-fashioned oven, whilst producing, with certainty, far better results. The cooker constitutes a rather heavy load—2 or 3 kW being necessary to prepare meals for six or eight persons—but the full load is only required for half an hour or so, whilst heating the oven, and the consumption can be greatly diminished during the remainder of the operations. The average consumption of energy for cooking is about 0.6 kWh per head per day. The electric cooker can roast, bake, boil, grill, fry, and steam all kinds of food, and gives off no fumes or disagreeable odours, whilst it is also perfectly clean and always ready for use at a moment's notice.

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Electric Heating. Another popular application of electricity is to radiators (Fig. 20), which can be carried about and used in any part of any room, giving off no fumes, and being therefore absolutely

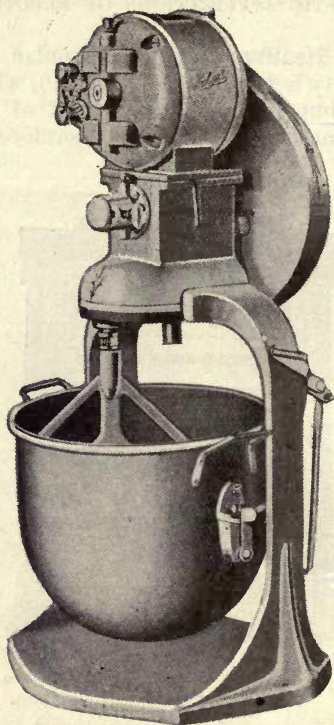


Belling & Co.

FIG. 20.—ELECTRIC RADIATOR.

Hot-wire type; giving an appearance and effect closely resembling those of a coal fire.

harmless to health. Whilst this system of heating is too costly for general house warming, except where ample waterpower is available, it is ideal for local heating, and with a radiator one can be perfectly comfortable in a room which is otherwise quite cold. The radiator can be switched on at pleasure, and instantly emits a cheerful glow accompanied by a torrent of heat which can be



Hobart Electric Co

FIG. 21.—ELECTRIC KITCHEN MACHINE.

The small electric motor at the top of the machine is geared to a vertical spindle to which any one of a number of implements can be attached for preparing foodstuffs placed in the detachable vessel. The motor can also be applied to a variety of other services and the machine is so arranged that all parts can be kept clean.



General Electric Co., Ltd.

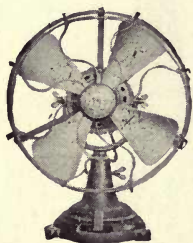
FIG. 22.—“TIME-SAVER” ELECTRIC WASHER.

The dolly is driven by a $\frac{1}{4}$ -h.p. motor which is placed below the tub, out of harm's way. A control handle causes the wringer to be driven forwards or backwards from the same motor.

directed wherever desired; there are no ashes to sweep up, and the apparatus needs no cleaning other than the usual dusting.

Other applications of the heating power of electricity are to bed-warming, keeping baby's food hot all night, making tea, coffee or toast on the breakfast table, heating curling tongs, etc.

Electric Power. Electricity also lends itself to many domestic operations which otherwise entail the expenditure of manual labour. By pumping water to an elevated tank whence it can be piped to the kitchen and bathroom, one of the most coveted advantages of city life can be secured. A kitchen machine (Fig. 21) can be had which will grind coffee, etc., shred vegetables, mix custards and soups, chop meat and make sausages, beat eggs, and otherwise prepare food for cooking, not



G. E. Co.

FIG. 23.
ELECTRIC FAN.

only at a minimum of expense—for it is driven by a very small motor—but also with surprising economy, owing to its making possible the use of parts of vegetables, etc. which would ordinarily be consigned to the dust-bin.

The electric washing-machine (Fig. 22) dollies clothes, wrings them, and saves a vast amount of labour in the laundry. Towel-driers and hot linen cupboards are useful in the bathroom, electric fans (Fig. 23) are useful everywhere, and the electric hair drier blows a breeze of heated air over the coiffure. Polishing machines brighten

the silver, the electric suction cleaner removes dust from carpets, and the floor-polisher serves the purpose indicated by its name. Lastly, the portable electric kinematograph enables the owner to give a moving-picture entertainment in his drawing-room, accompanied, if desired, by a faultless performance of the works of the greatest composers on the electric piano. All these and other advantages are at the service of the farmer who enjoys the privilege of a supply of electricity.

Electric Communication. Whilst the telephone is in no way connected with the use of electricity in the household, and can be installed entirely independently thereof, it undoubtedly claims a place in this book. A telephone places the farmer in direct communication with every other user of the public telephone system throughout the country and not only enables him to ascertain the latest market prices, to buy and sell, to manage several farms from one centre, and to give instructions to tradesmen, etc., but also brings all his neighbours who are similarly equipped within speaking distance at any hour of the day or night, affords instant communication with the doctor or the veterinary surgeon, and provides his household with a channel for conversation with their friends, which greatly relieves the loneliness of families scattered over the countryside, especially in the winter. In the rural districts of Ontario every other house is provided with a telephone, and in the Province of Alberta there are few farmers without one.

Unfortunately the public telephone service in

this country is at present much more costly than it ought to be, but that is another story—to which a happy conclusion may yet be written. Apart from the public telephone service, an intercommunication telephone system connecting the farm-house with the outbuildings, workmen's cottages, and other points on the farm is easily installed and may prove of the greatest value as a time-saver, besides affording a convenient means of keeping in touch with operations at all points without personally visiting them.

Consumption of Power. Some data regarding the power consumed by the appliances mentioned in this chapter may be of use to the reader. It should be observed that as a rule few of these appliances are simultaneously in use, so that the maximum power actually demanded is usually but a small proportion of the maximum possible demand calculated as the sum of all the ratings of the individual appliances. As innumerable patterns of domestic appliances are made, varying in size and power, the data in Table I opposite must be regarded as approximate.

Knowing the power consumption of an appliance, in watts, the cost of electricity consumed, in pence per hour, is obtained by multiplying the consumption (in watts) by the cost of electricity (in pence per unit) and dividing by 1,000. For example, the cost of electricity for a 30 candle-power (40W) lamp, using electricity at 8d. per unit, is $40 \times 8 \div 1,000 = 0.32d.$ or about $\frac{1}{3}d.$ per hour. Actually, the cost of electricity is much less than 8d. per unit to a farmer using electricity for a variety of purposes (*see* Chapter XI, p. 109).

TABLE I
 APPROXIMATE POWER CONSUMPTION
 OF ELECTRICAL APPLIANCES

Appliance.	Power Consumption in Watts.
Vacuum lamp of 15 candle-power . . .	20
" " 30 " . . .	40
Gas-filled lamp of 200 candle-power . . .	120
Radiator, according to size	500-3,000
Laundry iron	400
Cooker, according to size.	2,000-6,000
Bed-warmer	30
Hot-plate (for table use)	600
Toaster	350
Kettle	500
Griller	1,100
Fan	30
Kitchen machine	150
Washing "	250
Towel drier	200
Boot cleaner	200
Hair drier	500
Refrigerator	250
Suction cleaner	125
Sewing machine	100
Knife cleaner	200
Soldering iron	200

CHAPTER V

ELECTRIC DRIVING IN MECHANICAL OPERATIONS

IN this chapter we are mainly concerned with the use of electricity to perform duties of mechanical driving for which steam or oil engines would otherwise be necessary.

Advantages of Electricity. Farming differs from all other industries in that the farmer does not enter into contracts to any great extent. He cannot count upon either crops or prices, he is to a high degree dependent on the weather, and he puts a large proportion of his produce into store. He has to look ahead some 15 months, and regulate his actions in accordance with very uncertain estimates. Moreover, his work is irregular, coming with a rush at times, whilst at other times his men are practically idle for long periods. Any means that will enable the work to be spread out over the day and year should be welcomed, and in view of the continuous depletion of the rural population, any device that will reduce the monotony of farm life is highly desirable. These functions are admirably filled by electricity, which provides for cheerful lighting without fire risk, and being available at any moment and in any weather, enables farming operations to be so regulated as to reduce the "peak" loads and fill up periods of inactivity. It is an ideal motive

power for the farm—flexible, easy to control, safe in the hands of unskilled workmen, economical of manual labour, and cheap. The electric motor has a large overload capacity, takes very little power on light load, requires the minimum of attention, and lasts for years without needing repair. In order to meet modern conditions, farming should be made as far as possible analogous to factory operation; large farms should be run, large fields should be cultivated, and the utmost possible use should be made of machinery. In a paper read before the Institution of Electrical Engineers, Mr. R. Borlase Matthews enumerated well over a hundred different uses for electricity in farming, of which some 40 were actually in operation on his own farm or were about to be adopted there.

Scope for Development. It has been estimated on the basis of the industrial census of 1906 that in Great Britain at that date there was in all some 213,000 h.p. of steam, gas, and oil engines in use on farms, steam constituting about one-half of the total. By this time the figures must have been doubled, but even so they represent a mere fraction of what might be attained. It is stated that some 100,000 potential farm consumers are situated within five miles of electric power stations in this country, representing, on the basis of actual experience, a probable demand of 3,000,000 lamps and 500,000 h.p. to commence with; and there remains an enormous number of farms beyond the limited radius above-mentioned.

At Hereford, where the supply of electricity to farms has been developed far more than at any

other British centre, the farmers eagerly seek connection to the system, and take energy costing £25 a year on the average. Similarly in Canada, the use of electricity on farms is very general; in Ontario it is supplied from the three-phase lines of the Hydroelectric Power Commission. In France the co-operative system is widely adopted, either to generate power or to obtain bulk supply; the societies are assisted by special district banks, which are supported by the State, and special credit is afforded to agricultural interests. In 1914 there were nearly 100 such banks in existence. In Germany there were in 1913 650 co-operative societies supplying electricity for agricultural purposes.

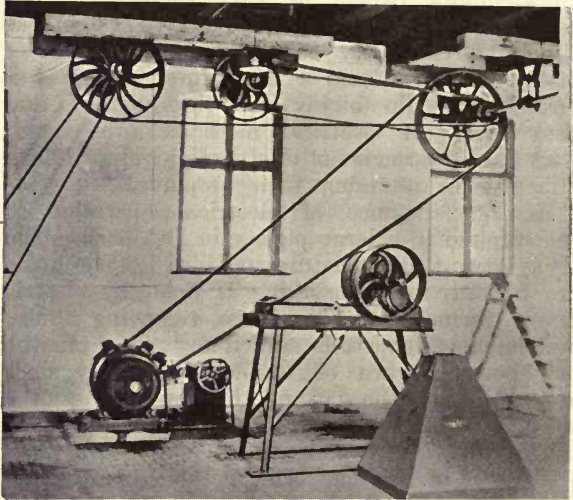
Examples of Electrical Operation. In April, 1920, a Departmental Committee of the Ministry of Agriculture and Fisheries submitted a report on Agricultural Machinery (Cmd. 506) in which the advantages of electricity for farming operations were emphasized officially. Amongst those mentioned were simplicity, low first cost, inexpensive foundations, easy starting, portability, low consumption when running idle, large overload capacity, small wear and tear, little attention required, even turning, rotary motion, etc. One witness stated that on a farm of 800 acres in Sweden, practically every machine except those used for cultivation was electrically driven. Whereas, before the use of electric power, the farmer had had to employ 10 horses, 16 men, and 4 boys, he was now able to do the same work with 1 horse, 7 men and 2 boys; the product was of increased value, due to the smoother working of

the machinery, he could thrash much earlier, obtaining a higher price and avoiding loss through the ravages of rats and mice, and he made a total saving of £5 a day on the thrashing operation. In Denmark (where in 1917 there were 271 co-operative societies) one co-operative system was supplying electricity to 3,000 farmers, besides other consumers, and a new power station was being built. So highly are the comfort and convenience of electrical methods appreciated, that Danish farmers not electrically equipped have difficulty in retaining their employees.

Another instance of electrical operation is to be found in a large pig-sty in Denmark. The sty is a two-story structure, in which 1,000 animals are housed, and everything is done by electric power, including grinding corn, removing refuse, and fetching foodstuffs and young pigs from the neighbouring town of Randers. Railway lines are laid all over the sty, and three men do all the work.

Methods of Driving. The methods of applying electric power to the machines depend on whether the latter are stationary and under cover, or portable. In the former case the simplest plan is to install a motor driving a countershaft by belt (Fig. 24); the shaft is fitted with pulleys of various sizes, according to the speeds at which the respective machines have to be driven. The motor should be of not less than 5 h.p., and should be suitably enclosed to prevent the access of dust and dirt to the interior; for this purpose the machine itself may be of the totally enclosed type, or at least of the "enclosed ventilated" type, which is

somewhat cheaper. If the supply is direct current, the motor will be shunt-wound ; if alternating, it will be of the squirrel cage induction type.



By courtesy, British Electrical Development Association.

FIG. 24.—ELECTRIC MOTOR DRIVING FARM
COUNTERSHAFTING.

At small expense countershafting and pulleys can be arranged so that a number of machines can be driven from one motor.

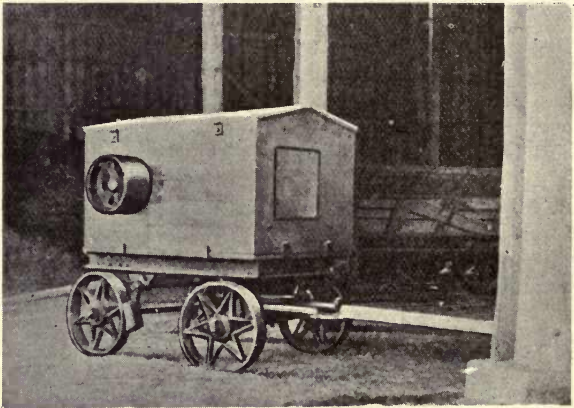
The motor should be bolted down to a concrete or timber foundation, and should be surrounded by a fence or guard to prevent damage and to keep the belt free from interference. A very good alternative is to bolt the motor to the ceiling rafters ; as ball bearings are commonly fitted to

small motors nowadays, the motor will not need lubricating for months at a time, and it is well out of the way overhead, besides which the horizontal belt drive is better than a sloping drive, and the belt is removed from ready access. Although fire risk is very remote, it is advisable to shield the flooring over the motor with thin sheet-iron ; this applies also to the starting gear, if the latter is attached to a wooden partition. The centre line of the motor should be not less than 10 ft. from that of the countershaft, as the motor will generally run at 1,000 or 1,500 r.p.m., and the shaft at 150 or 200 r.p.m., so that the pulleys will be of widely different diameters. The driven machines are bolted down to the flooring, and should be provided with fast and loose pulleys, so that any one of them can be started at pleasure, by shifting the belt. The countershaft should run in ball bearings or self-oiling bearings, as it is not likely to receive frequent attention.

For small operations such as churning and cream separating, it is preferable to use a much smaller motor, either a separate motor to each machine, or a single one so arranged that it can be used to drive any one of a number of machines.

Portable Motors. For driving out-door machines, a portable motor is required ; this can be mounted on a carrier fitted with handles for manual transport, if of small power (up to 2 h.p.), but for such work as driving thrashing machines a motor of from 5 to 25 h.p. is required, and this being too heavy for handling must be mounted on a wheeled truck (Fig. 25), on which it remains whilst at work, the wheels being spragged to prevent

movement. The starting gear should be mounted on the same truck, and a length of cab-tyre sheathed cable should be provided, long enough to reach from the working position to the nearest wall-socket. Portable motors should always be provided with rain-proof and dust-proof covers, and



By courtesy, British Electrical Development Association.

FIG. 25.—PORTABLE ELECTRIC MOTOR OF 30 h.p.

The motor is mounted on a light but rigid truck with broad wheels suitable for running on soft ground. The machine is protected by a detachable casing of sheet metal through which penetrates the shaft carrying a driving pulley. Thrashers or other machines are belt-driven from this pulley in the usual way. The motor is supplied through a trailing cable from a plug and socket or from a tapping on overhead lines.

as they run at high speeds but drive slow-running machines, they are often fitted with reduction gearing having a ratio of about 1 to 6. A 2-h.p. motor and cradle, with reduction gear and cable, weighs about 2 cwt., and can be carried by two men.

Power Data. Table II gives the horse-power required for various machines employed on a farm of, say, 300 acres.

TABLE II.—HORSE-POWER REQUIRED FOR
VARIOUS FARM MACHINES

Machine.	Capacity per ten-hour day.	Horse-power required.
Chaff cutter	10 tons	4-5
Root „	6-7 „	2-3
Potato crusher	20 „	1
Oat crusher	2 „	1
Miscellaneous pumps	100-1,000 gall. <i>per hour</i>	$\frac{1}{2}$ -1 $\frac{1}{2}$
Manure mill	30 tons	2-3
Portable thrasher	200 bushels	3-8
Grain cleaner	8-16 tons	1-3
Winnower	7-10 „	$\frac{1}{2}$
Drum thrasher with cleaner	550 bushels	25
Hay and corn hoist	30 tons	1-2
Flour mill	$\frac{1}{4}$ - $\frac{1}{2}$ ton	2-4
Band saw, or shearing machine	—	1
Milking machine	—	1-3
Cream separator	1,300 lb. <i>per hour</i>	1 $\frac{1}{2}$
Cider milling	—	2 $\frac{1}{2}$
Ensilage cutter	55 tons	10

Dr. F. C. Crowley gives the following data for power applications associated with farming—

	Horse-power.
Dairy work (churns and kneading machines of large size)	3-5
Cart-making and joinery (lathes, saws, and drilling machines)	3-5
Sawmills (saws and grindstones)	3-8
Lock-making and smith's work (lathes, drills, grindstones, bellows, etc.)	1 $\frac{1}{2}$ -3
Bakeries (kneading machines)	1 $\frac{1}{2}$ -3
Butchery (meat-beating, mincing, sausage-making)	2-3

The same authority states that a motor of from 2 to 5 h.p. will cut in an hour up to 20 cwt. of chaff with a consumption of 0.1 to 0.3 kWh per cwt. It usually takes a man an hour to cut 1 cwt. by hand, and 2 horses and a driver can cut from 3 to 4 cwt. per hour. For turnip cutting the consumption is from 0.01 to 0.02 kWh per cwt., and for oat crushing about 0.25 kWh per cwt. A motor of 1 h.p. can deal with 460 gallons of milk per hour, the consumption for separating, churning, and kneading the butter being 1.14 kWh per 100 gallons.

According to Mr. R. Borlase Matthews, the annual cost of a horse and driver is £148; 550 kWh of electricity will do the same amount of work, costing, even at 1s. per kWh, only £27 10s. Manual labour costs as much as electricity at 15s. per kWh.

Milking by Electricity. A byre containing ten cows requires a motor of 1 h.p. to drive the milking machine. Several cows are milked at the same time, and from 10 to 15 can be milked per hour by one man tending three or more milkers at once. In a farm at Hereford 70 cows are milked twice daily with a machine driven by a motor of 8½ h.p.

Ensilage Cutting. In Canada ensilage is cut and silos are filled with electrically driven machines; ensilage cutting is an autumn load, and takes from 2 to 15 h.p. Larger equipments used in Canada take from 20 to 25 h.p., and both cut and elevate ensilage at the rate of from 10 to 15 tons raised 39 or 40 ft. per hour.

Nearly 100 German farms, Mr. Matthews states, use electricity for preserving green fodder. A

metal plate is laid at the bottom of the silo, and when the silo has been filled, another plate is placed on the top of the fresh green fodder. An electric current is then passed through the silage from one plate to the other for a period varying from one to two days, the energy consumed being from 13 to 20 kWh per ton.

An alternative treatment, recommended by the same author, is to stack the grass whilst green, and to blow air through the stack by means of an electrically-driven fan. In this way the grass is thoroughly dried and converted into excellent hay, of better quality than that produced in the usual way.

Mowing and Harvesting by Electricity. When mowing and harvesting machines are hauled by a tractor, the knives and binders are usually mechanically driven at a rate depending on the speed of travel. Mr. Matthews finds that if an electric motor fed with current from a dynamo mounted on the tractor is used for driving the knives at a constant speed, crops can be cut about one-third faster than by the usual method, and heavy and angled crops can be dealt with satisfactorily.

English Electrical Farms. On one of the farms supplied with electricity by the Hereford Corporation there are from 80 to 100 cows; a motor of $7\frac{1}{2}$ h.p., installed in a lock-up cabin, drives machines for cutting chaff, kibbling corn, and pulping roots for cattle food, as well as pumping. Electric light is installed in the cow-byres, foal yards, and farm-house, 30 lamps being used, of which 4 of 50 candle-power each are mounted in a bracket

fitting for lighting the yard. This farm consumed in one year 633 units for lighting, at $4\frac{1}{2}$ d. a unit, and 930 units for power at 3d. a unit, making a total cost of £23 a year; the average annual cost per farm is £20. The first cost of the electric farming plant is half that of steam or oil driven plant, and the fire insurance premium is greatly reduced. Moreover labour is less costly, and can be employed usefully on wet days in cutting chaff or kibbling corn.

Similarly, on a farm of 285 acres near Altrincham, 30 lamps were installed in the house and farm buildings, and the whole of the machinery was driven by a $7\frac{1}{2}$ h.p. motor fixed in the granary; the machines included a corn mill, chaff cutter, root pulper, cake mill, etc. The supply mains consisted of half a mile of concentric cable laid underground, and a transformer at the farm reduced the supply pressure of 2,000 V to 100 V.

At another farm in the North of England, electricity has been used since 1904; it is supplied at 500 V for power, and 250 V for lighting, from a station $1\frac{1}{2}$ miles away, by underground cable. There are 45 lighting points, and on account of the high voltage almost all the wiring is carried out in screwed steel tubing. The average annual cost of lighting over a period of 10 years was £5 13s. 4d. A 10-h.p. motor is used to drive line shafting, which extends through the wall of the motor house to the mill house, and drives a thrashing machine, bean bruiser, turnip pulper, cake bruiser, straw cutter, bone crusher for hen food, and small lathes and drilling machines in a workshop. A motor of 2 h.p. drives a churn and milk separator. It is also proposed to install a milking machine,

refrigerator, electric incubator, horse clipper, and washing machine, and electric heaters in the byre and milk house. The farm affords a useful type of load to the supply station, as the machines are used in the early part of the day, and the greatest demand for light and power occurs in the early morning. In 1906-7 this farm used 1,672 units for power, costing at 2d. per unit £14 5s.

Electric Progress Abroad. In Italy a network of 25 miles of high-pressure lines, with 20 distributing stations, has been installed on the Roman Campagna, and thrashing and pressing operations are carried out with portable transformers and motors, while owners of orchards install motor-driven pumps for irrigation. In Bavaria there are few farms without electric power, and near Lucerne there are over 1,000 farms electrically equipped.

The use of electricity is developed very widely in California, where rainfall is scanty. In 1915 electricity was supplied by fourteen companies to 10,583 installations, representing 190,000 h.p., and about 12,000 motors, of which 80 per cent were used for irrigation and the remainder for miscellaneous farming operations. The Californian farmers use electricity for cooking, ironing, driving washing machines and sewing machines, etc., more freely than city people, and petrol-electric generating sets are sold in great numbers. In Western Ontario 500 farms are connected to the supply mains. The advantages of electric power are so highly appreciated there that a farm with electricity available from the public mains is worth at least \$1,000 more than a similar farm which does not

enjoy that privilege. The system of supplying electricity to farmers originally adopted by the Hydroelectric Commission was based on the cost price of energy at the municipal boundaries plus the cost of carrying it over a special line to the consumer, but this was found to be commercially feasible only when there were at least three customers per mile of the route, and tended to favour unduly farms that were near the main roads. A better plan has been devised, according to which each district is treated independently, and all the consumers in that area are charged alike, the price diminishing as the number of consumers in the area increases. Eight classes of service are tabulated, ranging from the public lighting of a hamlet to farm service of the heaviest type; a fixed charge is made for the service, and a running charge depending on the consumption of energy—a system which is steadily growing in favour elsewhere also.

In Australia, on the big sheep farms, electricity is widely used for shearing sheep.

Electricity in Horticulture. Turning to horticulture, for market gardening electricity has many uses. The chief application is to pumping, for which purpose an electric motor is immensely superior to a gas engine, requiring no attention and taking up little space; it can be controlled automatically by the height of water in a tank, and the cost of maintenance is trifling. A 10-h.p. motor will lift 20,000 gallons of water per hour to a height of 50 ft., costing, at 2d. per unit, 1d. per 1,000 gallons. A motor pump can also be used to drive a circulator in the hot-water system, in which case

the boilers can be fixed on the ground level, uniform temperature can be maintained, and the pipes can be fixed at any desired level. Other applications are to stoke-hole pumps, spraying plants, chaff-cutting, screening soil, grading fruit, trolleys and conveyors for moving fruit or soil, automatic stoking, ventilation, etc. Electric light is also of great value in a nursery garden, for night work, and in sheds and offices, and in some cases experiments are being made with electroculture (*see* Chapter X). By the use of electric light in the spring, flowers can be induced to bloom at an earlier date than under natural conditions, and thus they can be placed on the market when prices are high ; this process is being adopted with great profit in certain market gardens.

Thrashing by Electricity. The driving of thrashing machines is, next to ploughing, the heaviest and most important power service in agriculture ; it is also one to which the electric method is most admirably adapted. Wherever overhead lines are available electric thrashing can be carried out in the fields, so that the grain and straw can be put into store separately, with the minimum of handling and without loss of time.

Thrashing machines may be obtained with a self-contained motor, but the ordinary belt-driven machines can be used in conjunction with a portable motor. The smaller machines require from 2 to 6 h.p. ; those which are fitted with straw presses, etc., and are usually driven by mechanical power require from 20 to 25 h.p. Dr. F. C. Crowley states that electric thrashing machines are widely used in Germany, where the following

results have been obtained for the energy consumed, in kWh per cwt.—Rye, 0.35–0.70 ; wheat, 0.35–0.60 ; oats, 0.25–0.50 ; barley, 0.30–0.55 ; mixed grain, 0.28–0.45. Mr. Matthews gives data from Dutch farms approximating to the lower values mentioned above.

Experience has shown that electric is much cheaper than steam thrashing, both in first cost and in working cost, especially where the power required is small or the working periods are short. The electric thrasher is extremely convenient in use, owing to its light weight and portability, its requiring no supplies of water and fuel, its independence of the weather (as it can be used indoors in wet weather with perfect safety), the ease with which it can be controlled, and its high efficiency even when working at light load. Moreover the uniformity of rotation of the motor results in a cleaner thrashing, a better product, and increased output. Actual measurements have shown an increase of from 1 to $1\frac{1}{2}$ per cent in the quality of grain produced by electric as compared with steam thrashing. By carrying out the work in two stages—thrashing and rough cleaning in one machine, and further cleaning, dressing, and grading in another—the work can be done with a motor of 5 h.p., employing fewer hands, and spreading the work over a longer period. Actual tests show that the power cost of a thrasher driven by an oil tractor is more than five times as much as with the electric motor at 5d. per kWh (R. B. Matthews).

CHAPTER VI

ELECTRIC PLOUGHING

Mechanical Ploughing. Of all the mechanical operations conducted on a farm, the most arduous and the most important is ploughing. It is unfortunate, therefore, that this is also the most difficult operation to deal with by mechanical methods in place of animal power. The work is distributed over a large area, every inch of which has to be operated upon, and in this respect ploughing, harvesting, and cultivation are distinguished from all other mechanical problems.

The simplest method of dealing with this class of work is certainly to use an automobile plough or reaper, which is independent of all other apparatus, and this is the solution which has most frequently been adopted in this country with the aid of the petrol engine ; but it has certain drawbacks, such as the great weight of the machine, which partly undoes the work of the plough by compacting the soil, the necessity of skilled attention, high first cost, high cost of fuel, and considerable fire risk. Agricultural tractors were built and purchased with headlong haste during the latter part of the war, but proved somewhat disappointing to their optimistic advocates.

Another solution to the problem is found in the system of hauling ploughs to and fro by means of stationary engines, usually steam engines, which is free from some of the objections to the

automobile apparatus, and has been in use for many years.

Both the above methods have been adapted to electrical operation, but the automobile electric plough can hardly be considered a promising device, being very heavy—though it is economical in working, and free from fire risk. The haulage system, on the other hand, lends itself readily to electrical operation, and has been adopted very extensively on the Continent. Apart from other advantages, it is cheaper both in first cost and in operation than steam haulage, and employs less labour, as there is no coal or water to be carried to the haulage engines.

As but little experience has been gained in this country, we must go abroad for data regarding working results. According to Italian experience in 1914, horse ploughing cost from 22s. to 24s. per acre, steam ploughing 18s., and electric ploughing 12s. 6d. per acre (with electricity at 1½d. per unit), all costs being included. Later data from Italy, published in March, 1920, illustrate the changed conditions; electric ploughing cost 26s. inclusive of labour, interest, and depreciation, while petrol tractors cost no less than 121s. 6d. owing to the excessive cost of fuel.

Electric Power Lines. Assuming that the cable haulage system is employed, the equipment is naturally divided into two sections: The line supplying power to the machines; and the haulage and ploughing gear. The line will consist of bare copper or aluminium conductors carried on wooden poles by means of porcelain insulators, and will work at a fairly high voltage,

owing to the considerable distance over which the power has to be transmitted. In the case of direct current, the highest practicable voltage 500 V, and two wires will be required ; this system would usually be employed in proximity to a town having a public supply at 500 V or thereabouts for power, connection being made to the mains at a suitable point through the necessary switches and circuit-breakers, with an electricity meter in circuit. There is, however, a farm in this country where a private generating plant working at this pressure is installed, to which we shall refer later (p. 72). More generally, especially when the distance from the public supply network exceeds a mile, the supply will be alternating, probably three-phase, and in that case three wires will be required, at a pressure of from 1,000 to 3,000 V, which necessitates insulators of higher quality, but allows of the use of much smaller wires or cables.

The farmer should not attempt to install the power line without the services of an experienced contractor, as any pressure above 200 V is capable, under certain conditions, of imparting a fatal shock to a man who accidentally makes contact with the bare wires. The line must therefore be of substantial construction and sound workmanship. Arriving at the field to be ploughed, the line should be carried along one side of it, at a height not less than 20 ft. where it crosses a roadway or cart track, and not less than 15 ft. elsewhere. The poles may with advantage be set in the hedgerow, out of the way. Connection is made with the line by means of special devices (*see* Figs. 13, 14, p. 35) designed to enable the operation to be carried out without danger to the unskilled user.

Cables and Transformers. A flexible cable—preferably of the tough-rubber-sheathed type—completes the connection to the apparatus, which is mounted on a wheeled truck or trucks. In the case of a 500-V direct-current supply, no transformer is necessary, the current being led to the motor through a double-pole switch, circuit-breakers (which are preferable to fuses), and an ammeter, which indicates the load on the motor. If, on the other hand, the supply is three-phase

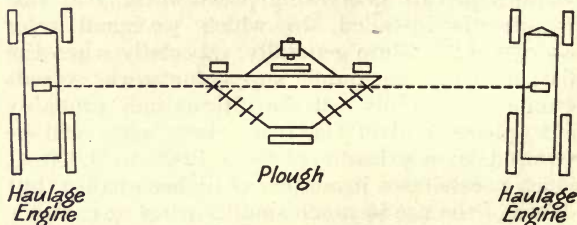


FIG. 26.—DIAGRAM OF DOUBLE HAULAGE-DRUM SYSTEM OF PLOUGHING.

A tilting plough is hauled to and fro by haulage engines at each side of the field.

alternating, at a pressure above 500 V, a transformer will be necessary to reduce the supply pressure to a moderate value, which should not exceed 500 V.

A separate truck is used for the transformer, (see Fig. 15, p. 37) the high-pressure connections and transformer being completely enclosed, so that the workmen run no risk of coming in contact with conductors at a dangerous voltage.

Plough-Haulage Systems. We come now to the haulage machinery, which may be arranged in

three different ways. One method is to use two single-drum haulage machines one on each side of the field to be ploughed, which haul the ploughs alternatively to and fro (Fig. 26); in this case a power line must be provided on each side of the field. Another method is to use one double-drum haulage machine, the cable passing round a pulley on an anchor carriage at the opposite side of the field, and the gear being reversed in direction at

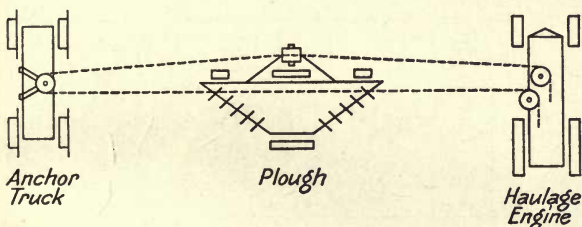


FIG. 27.—DIAGRAM OF SINGLE HAULAGE-DRUM SYSTEM OF PLOUGHING.

Only one haulage engine is required by this method of ploughing, the haulage rope passing round an anchor drum at one side of the field and being driven by a reversible double-drum haulage machine.

each end of a furrow (Fig. 27). The third method uses one stationary double-drum haulage machine, with two cables passing in opposite directions round the field over pulleys at the corners, and round pulleys at the ends of the furrow, alternately hauling the plough to and fro (Fig. 28). This system is used very widely in Italy; it has the advantage that the haulage machine is not moved until the whole field has been ploughed, and therefore long trailing cables are not required.

In all the systems considered the haulage gear consists of a motor driving a drum or drums,

through reduction gear, with clutches which enable the idle drum to run free when paying out cable. In the case of double-drum machines, the motor drives the drums alternately through suitable gearing, hauling-in the cable on one drum while the other pays it out. The motor should be of from 30 to 50 h.p., as the work is very heavy ; to plough a field 12 in. deep with multiple-share

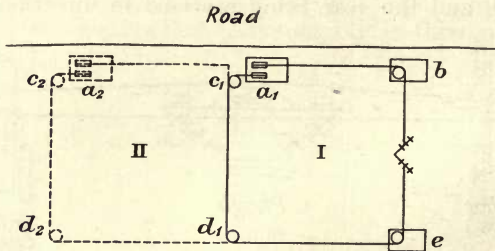


FIG. 28.—DIAGRAM OF TESCARI SYSTEM OF HAULAGE FOR ELECTRIC PLOUGHING.

A single, reversible haulage engine is used. The anchor trucks, *b*, *e* are moved to the left after each traverse of the plough. The haulage engine and the anchor drums *c*, *d* remain in the positions *a*₁, *c*₁, *d*₁, until the whole of field I is ploughed, whereupon they are moved to *a*₂, *c*₂, *d*₂, preparatory to ploughing field II.

ploughs covering a width of 3 ft. requires about 30 h.p., in heavy soil, but to allow for stones, roots, etc., 50 or 60 h.p. must be provided. In practice, a plough of this order would deal with about 8½ acres in a day of twelve hours.* At the end of each furrow the plough is tilted, as in steam ploughing, to make the return journey.

* Mr. R. Borlase Matthews states that a large haulage set will plough 19 to 20 acres a day, as compared with 1 acre by horse haulage.

Comparative Advantages. Amongst the advantages of the double-engine system of ploughing are the following: It is easier to adjust, requires less rope, can be used over uneven ground, and can plough furrows up to 650 yds. long. On the other hand it is costly to install, and requires a supply of power at both sides of the field.

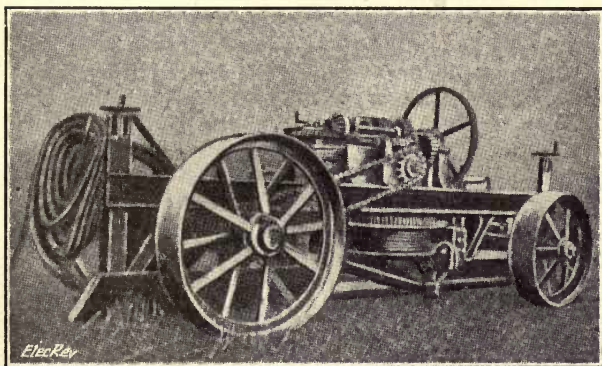


FIG. 29.—ANCHOR TRUCK, FILLET TYPE.

The truck is provided with an anchor plate, parallel to the length of the truck. This plate penetrates easily into the ground as the truck is moved forward but offers great resistance to tipping in the direction of the plough-rope pull.

The single-engine system, dispensing with one of the haulage engines but replacing it by an anchor trolley carrying a pulley (*see* Fig. 29), is otherwise very similar to the former; it has the advantages of cheapness, both in haulage plant and in electrical installation, but requires more rope, is more difficult to adjust, and cannot be used over hilly ground where the driver cannot see the signals of the ploughman.

The advantages of the third system have already been mentioned, but on the other hand, it requires a still greater length of cable and additional anchor pulleys, and is unsuitable for use on uneven ground.

An English Installation. As an example of the use of two single-drum haulage machines, we may take the farm of Mr. Chorlton at Cotgrave, near Nottingham, on which electrical methods have been in use since 1910. The farm has an area of 240 acres, and the soil is of a heavy nature, requiring three or four horses to haul a plough. Steam ploughing was tried, but proved unsatisfactory, and involved the services of two or three men and a horse to serve the engine, besides three men operating the apparatus. The electrical equipment includes a 25-h.p. suction-gas engine and producer, driving a 500-V dynamo in an out-building; this plant supplies electricity for lighting, as well as for the power requirements of the farm.

The current is carried to the various parts of the farm by overhead lines of bare copper, with which connection is made by flexible conductors, which are attached to the lines by hooks and slide along them as required. The electric ploughing tackle comprises two trolleys which are fitted with electrically driven haulage gears, and travel along opposite sides of the field under cultivation, hauling a reversible three-furrow plough to and fro between them by means of a cable. After each journey the trolleys are moved forward by hauling on a cable anchored at the far end of the field, by means of a cable drum mounted on the

trolley. The plough hauling rope is 400 yds. long, and weighs half a ton ; it is capable of sustaining a pull of 5 tons if required. A 25-h.p. winch can haul the three plough-shares through the heaviest and stickiest clay, ploughing 8 or 9 in. deep and 9 or 10 in. wide. The haulage trolleys weigh 4 tons each ; they would be more convenient to handle if they were made capable of propelling themselves. The trolley motors are fitted with pulleys, so that when they are unclutched from the winding drums, they can be used to drive thrashing machines, etc., by means of leather belts ; they are also suitable for harrowing, mowing, cutting drains, etc., and are operated by the farm hands. It is stated that a field 289 yds. square, of heavy clay soil, can be ploughed 8 in. deep with an expenditure of $1\frac{1}{2}$ tons of coal. Nine miles of single furrow can be cut per hour, consuming 8 kWh, which at 2d. per unit would cost 1s. 4d. (to which must be added the cost of labour, capital charges, etc.).

Automobile Ploughs. While the use of an automobile plough, equipped with a storage battery, has been considered, the great weight of such an outfit detracts from its efficiency, owing to the compression of the soil by the wheels of the tractor. An alternative method is to employ a motor plough, connected to the supply line by a trailing cable, which is paid out and picked up again as the plough passes to and fro. In order to provide a positive means of haulage, a chain is stretched across the field between anchors, and the motor on the plough drives a wheel which engages with the chain. This type of plough has a high

efficiency, and is light, comparatively inexpensive, and completely under the control of the ploughman. A motor of 15 to 20 h.p. suffices to operate the equipment. The complete plant, with 275 yds. of chain, two anchors, 650 yds. of trailing cable, and 6 wheeled supports for the cable, is said to cost from £355 to £600, according to the size of the motor. Steam haulage gear would cost from five to ten times as much. The cost of ploughing 14 in. deep is given as about 9s. per acre, with electricity at 2d. per unit.

Continental Progress. On the Continent great progress has been made in the development of electric ploughing. A German haulage gear is provided with two speeds— $2\frac{1}{2}$ and $3\frac{1}{2}$ miles per hour—and the carriage is self-propelling, the motor being coupled either to the cable drums or to the rear wheels, at pleasure. The haulage drum is driven by belt, so that in the event of stoppage of the plough by roots or large stones, the belt slips and no damage is done to the machinery. The same driving pulley can be used to drive thrashing machines, etc. The anchor carriage used with a single-haulage truck weighs about 4 tons, and is provided with disk-shaped wheels to bite the ground; it can be advanced by power derived from the haulage cable as the work proceeds. A serious objection to the outfit is the great weight of the haulage engine, which is no less than 13 tons. A French equipment is much lighter, the truck weighing 4 tons with a motor of 45 h.p., and exerting the same maximum pull as the German plant, viz., 8,800 lb. The truck is self-propelling, and is anchored by a spade, which is first driven

into the earth by two handwheels, and afterwards cuts its way through the soil as the truck advances, a coulter being provided in front of it ; with this mode of anchoring, a pull of 57,000 lb. can be withstood. The anchor spade is 13 ft. long, and can be driven 10 in. deep if necessary, giving an earth resistance of 10·8 sq. ft. whilst a three-share plough 13 in. deep ploughs only $3\frac{1}{4}$ sq. ft., so that there is an ample margin of anchorage.

Power Supply. The main difficulty in electric ploughing is to convey the power to the motor. A motor of 50 h.p., which is often used, cannot be supplied economically at a less pressure than 500 V, and even at this working voltage, a high-pressure line must be run across the fields and connected to the haulage-car through a step-down transformer. The high-pressure line must be tapped at various points, and in order to do this with safety to the workpeople, various ingenious devices may be employed. The transformer truck should be divided into two compartments, to house the high and low pressure apparatus respectively (*see* Fig. 15, p. 37). In the high-pressure side are situated the transformer and circuit-breakers ; in the low-pressure side the fuses, a meter, instrument transformer, low-pressure terminals for the trailing cable, and a drum for the latter. The truck weighs about 3 or 4 tons when loaded, and is arranged for horse traction.

The trailing cable, for a three-phase motor, has three cores of 0·04 sq. in. each, and is provided in lengths of 300 yds., which can be joined together with male and female connectors ; its life is greatly increased if it is supported clear of the

ground, light supports being available for this purpose.

Mr. R. Borlase Matthews has described a French portable plant comprising a 50-h.p. petrol tractor to haul the apparatus from farm to farm, a motor of 125-h.p., a portable 5,000 V overhead transmission line and trailing cables, and steel plough ropes, the equipment being guaranteed to plough 25,000 acres per season.

Cost of Ploughing. The cost of ploughing with horses or oxen is from 24s. to 40s. per acre, being generally nearer the higher figure (on a pre-war basis). In order to use mechanical ploughing economically, the plant must be kept at work as continuously as possible. The figures in Table III relate to a ten-hour day, throughout the ploughing season (a condition which can only be fulfilled on a large farm, or by the co-operation of a number of small farmers). The area ploughed would be 1,240 acres (deep) or

TABLE III
COST OF PLOUGHING BY VARIOUS SYSTEMS
(Pre-War Values)

System.	Deep Ploughing (12-14 in.) Cost per acre.	Ordinary Ploughing (7-8 in.) Cost per acre.
	<i>s. d.</i>	<i>s. d.</i>
Steam haulage engines . . .	22 9	12 10
Petrol tractor	—	18 —
Electric haulage engines, with energy at 1d. per unit	16 6	11 4½

2,470 acres (ordinary) by haulage, and 650 acres by tractor. The capital charges form a large proportion of the cost, and therefore arrangements should be made to keep the plant engaged throughout the ploughing season, by co-operation between adjoining farmers if necessary; further, the haulage plant should be used for other purposes, such as harrowing, mowing, thrashing, etc., whereby the proportion of the capital charges allocated to ploughing is reduced.

It should be observed that where the subsoil is good, deep ploughing results in crops heavier by 20 to 35 per cent than ordinary ploughing, and that deep ploughing by electricity is much cheaper than by steam.

In Italy, in 1914, ploughing 100 days per annum, it was found that the cost was 21s. per acre with steam, and 14s. per acre with electricity at 2d. per kWh. In 1920 experiments with the Violati-Tescari-electric system showed that an acre could be ploughed at a cost of 26s., including all capital charges, the enhanced cost of labour, etc. Using tractors the cost was nearly four times as much, owing to the high cost of fuel.

According to data from the Rothamsted experimental farm, ploughing can be done with a tractor three or four times as quickly as with horses, and thus full advantage can be taken of favourable weather; all the ploughing can be done before Christmas, leaving time in the spring for extra ploughing, which immensely improves the crops. It has been found that the bacteria which fertilize the soil are most active in the autumn, and that the earlier and quicker land is ploughed, the greater is its fertility. A 10-acre field can be

ploughed in two days by one man with a tractor, at a less cost (at present wages) than before the war with horses.

Power Required for Ploughing. As information regarding the mechanical aspects of ploughing is not generally available, the following particulars may be found useful. It has been found by experiment that to plough light soil requires an effort of 740 to 820 lb. per sq. ft. ; heavy soil, 1,125 to 1,230 lb. ; four-year lucerne, 1,780 lb. ; heath land, 1,260 lb. Denoting this effort by c , the horse-power required to haul the plough at the rate of v ft. per sec., when ploughing a furrow w ft. wide and d ft. deep, is given by the formula—

$$\text{Horse-power} = c \times w \times d \times v \div 550.$$

The value of v does not usually exceed 3 miles per hour, or $4\frac{1}{2}$ ft. per sec. From this formula, the horse-power required to plough 3 ft. wide, 8 in. deep at 3 m.p.h. in light soil, would be $800 \times 3 \times \frac{2}{3} \times 4\frac{1}{2} \div 550 = 13$ h.p. In heavy soil, under the same conditions, the power required would be $1,200 \times 3 \times \frac{2}{3} \times 4\frac{1}{2} \div 550 = 20$ h.p. A margin of power, however, must be allowed for large stones and other obstructions, and for this reason the haulage engine should be able to exert twice the normal force.

As there are 43,560 sq. ft. in an acre, the area that could be ploughed by a plough 3 ft. wide, at 3 m.p.h. ($4\frac{1}{2}$ ft. per sec.), apparently would be $3 \times 4\frac{1}{2} \times 3,600 \div 43,560 = 1.1$ acres per hour, or 11 acres in a ten-hour day ; but in practice

delays occur, and it may be taken that 8 acres would be nearer the mark.

Mr. R. Borlase Matthews gives the following figures for actual results obtained with electric ploughing equipments—

TABLE IV
CONSUMPTION OF ELECTRICITY FOR PLOUGHING

Depth of furrow, inches.	Acres ploughed per hour.*	Consumption per acre, kWh.
6	2.5-3	14
10	1.8	18
12-12.75	1-1.25	24
10 plus 6 subsoiling	1.25-1.4	36-40

* Acres per hour depends on capacity of ploughing set.

CHAPTER VII

ELECTRIC HAULAGE

Electric Vehicles. Vehicles propelled by electricity are not often met with far beyond the outskirts of towns, mainly because they are not conveniently adapted for long journeys. The reason for this is that charging stations are not yet available at the roadside, whereas petrol can be purchased anywhere ; no doubt this deficiency will be remedied in the future, for electric vehicles are gaining in popularity, and electricity supply authorities are learning to appreciate the value of this outlet for their product, as well as their duty to fulfil a public want. In the meantime, however, we must take the situation as we find it, and admit that in most parts of the country charging stations are lacking. An electric wagon can traverse a distance of about 40 miles before requiring a fresh charge ; unless it is known that the charging can be done at the end of the journey, to enable the vehicle to return, it is obvious that the maximum radius of operations from the home charging station is 20 miles, and it is wise to keep a few miles in hand, so that an outward journey of 15 or 16 miles is about the working limit. However, this radius should be ample for most of the requirements of the farm, and the electric vehicle offers so many advantages for farm use that it is worth while to give a brief account of its characteristics.

Propelling Apparatus. The body of an electric vehicle may take a variety of shapes—open or covered, van or wagon, or provided with seats for passengers—but the propelling mechanism always consists of three essential components—one or two electric motors, a battery of accumulators, and a controller. The motors are of a special design to withstand the weather and to exclude dust and damp from the interior; they are sometimes mounted in the wheels themselves, but are more often geared to the wheels with chains and sprocket wheels. When one motor is provided for each back wheel, no differential gear is required, nor is there a clutch or Cardan shaft; the mechanism is therefore extremely simple and reliable. The battery is housed in a box slung under the chassis, and is of a type specially developed to deal with the severe conditions of loading to which it is subjected; it may be of the lead and sulphuric acid type, or of the nickel-iron-alkali type, the former having advantages in operation and the latter a much longer life. Usually the working voltage of the motors and battery is 80 V, and the charging voltage about 100 V. The controller is a kind of electric switch, taking the form of a rotatable drum enclosed in a casing; it enables the motor to be driven forwards or backwards at any speed within the compass of the equipment. Suitable brakes are provided, and for use in hilly country it is possible to provide means for charging the battery whilst running downhill, thus recovering some of the energy expended in propelling the vehicle uphill. For haulage on cultivated land the rims of the driving wheels have to be fitted with strakes

to secure adhesion, which hinder the use of vehicles on roads; to overcome this difficulty an Italian firm has devised sets of detachable rubber blocks, which can be bolted on the rims, thus in a few minutes converting a land tractor to a road vehicle.

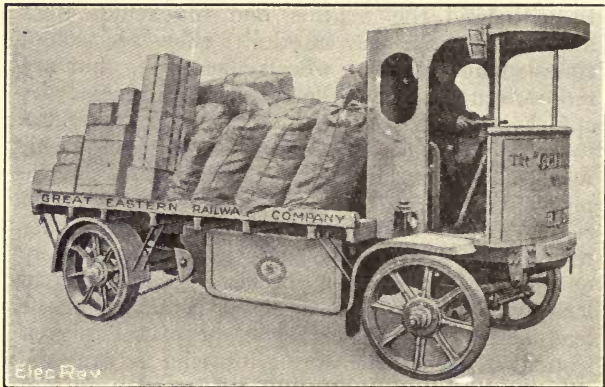


FIG. 30.—“GARRETT” ELECTRIC LORRY. 3½-TON MODEL.

The storage cells are hung beneath the chassis in the casing below the sacks in this illustration.

Ease of Control. An outstanding feature of the electric vehicle is the perfect ease with which it can be controlled. It is no exaggeration to say that in an hour any person of average intelligence can learn all that there is to learn in this connection, and in fact the “electric” is absolutely unapproached by any other type of automobile in this facility of management. On this account it is particularly well adapted for use by women, if necessary. Repairs are so seldom required, that

the vehicle can be kept constantly in use, and the difficulty in starting which is not infrequently experienced with petrol vehicles is entirely absent ; provided that the battery is not exhausted, the electric vehicle can always be started at a moment's notice without any muscular effort.

Industrial electric vehicles are made for loads from $\frac{1}{2}$ ton to 5 tons, a useful size being the 2-ton van, or $2\frac{1}{2}$ -ton lorry ; the normal speed is from 9 to 12 miles an hour on the level. The driver's seat is on the front of the vehicle, and is usually protected with a canopy (*see* Fig. 30). The battery, in the case of the 2-ton vehicle, weighs from 17 to 21 cwt., according to the maker, and comprises from 40 to 44 lead cells, or 60 nickel-iron cells.

Battery Charging. There are three methods of charging the battery : at constant current, at constant pressure, and by "boosting." The first is the normal method ; the current is maintained at a steady value, which is stated by the makers, until the battery begins to give off gas, when the current should be decreased somewhat, and continued until all the cells are gassing freely. This method of charging requires a maximum voltage, at the finish, of 2.6 V per cell, or 110 V for a 42-cell lead battery ; the same voltage would suit a nickel-iron battery of 60 cells. During the earlier part of the charge a voltage of about 2.2 V per cell is sufficient in the case of a lead battery, so that some 18 V would have to be absorbed in a regulating resistance. In the second method of charging, the full voltage is applied at the start (about 2.3 V per lead cell, or 1.67 V per

nickel-iron cell), and a strong current flows, which gradually diminishes as the battery becomes charged. This is a very convenient method, as no attention is necessary after the charge is commenced, but an extra full charge at a higher voltage should be given occasionally. "Boosting" consists of giving the battery a partial charge at a rapid rate, and is very similar to the constant-pressure method; its special function is to refresh a partly discharged battery in a short time, for instance, whilst the driver is having lunch at a market town, after a long run which has depleted the charge unduly. By this method a battery which has been half discharged can have one-third of its full charge put in within an hour, or if it has been fully discharged, the same time suffices to give it half its normal charge. Where it is possible to arrange for boosting charges *en route*, the radius of action of the vehicle is increased materially.

If the supply pressure at the farm is 100 or 110 V, direct current, charging is a simple matter. If the current is alternating, or at a different pressure, a motor-generator will be necessary, consisting of a small motor driven by the farm supply, and driving a dynamo which generates current at a pressure suitable for charging the battery. A direct-current supply at 200 or 220 V could be used without a motor-generator, by inserting resistance in the charging circuit, but this is a wasteful system. An alternative to the motor-generator, in the case of an alternating-current supply, is a mercury vapour rectifier, which has no moving parts, and converts the current to direct current for the battery.

Generally a transformer would be required with the rectifier, to give the correct voltage, and as there is a constant drop of 20 V or so in the rectifier, the system is not much more economical than the motor-generator, but it is a simple and convenient device. In either case there is required a small switchboard, equipped with an ammeter, a voltmeter, and an automatic switch to ensure the correct charging of the battery, which might otherwise be reversed, or mishandled in other ways. There is, however, no difficulty in the operation.

Uses of Electric Vehicles. The vehicle, when made in the form of a wagon, can be arranged to tip its contents, and this operation can be effected with power derived from the battery. As a milk-cart or delivery van, the electric vehicle is ideal, as it is at its best when making short runs with frequent stops; under these conditions it is far superior to horsed or petrol vehicles both in economy of capital and labour, and in the rapidity with which it makes the round. For this reason the electric wagon for collecting refuse has been adopted very widely by local authorities, the saving effected by its use having been demonstrated repeatedly. For collecting certain crops, or distributing manure, the electric wagon is well adapted; whenever it stops, the motor stops, and consumes no energy, whilst it can be started again with a movement of the controller handle. A petrol engine, on the other hand, is usually kept running during short stops, consuming fuel; if it is stopped, it has to be started again laboriously before the vehicle can be moved.

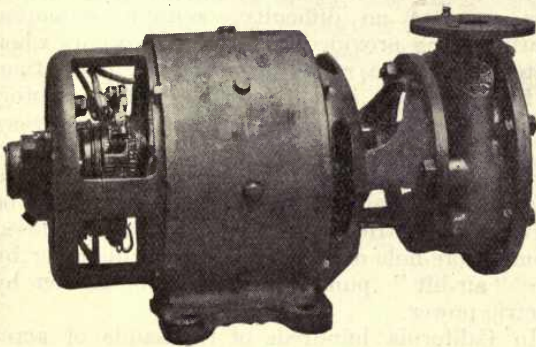
CHAPTER VIII

PUMPING AND IRRIGATION

Pumping by Electricity. One of the applications of electric power which is needed most commonly on a farm, and for which it is suited most admirably, is pumping water, for use in the house or farm buildings, or for irrigation. -Quite frequently small pumps are operated by wind-power, from a wind-rose mounted on a tall steel tower, and driving a reciprocating pump, but where electricity is available it is far better and cheaper to install a small motor driving a centrifugal pump (Fig. 31), by which an abundant supply of water can be raised from a depth of 25 ft. to any height up to 100 ft. (or higher if necessary, with a more expensive type of pump).

The installation of such a pumping outfit is simple, the pump and motor being mounted together on a cast-iron bedplate which is bolted down to a timber or concrete foundation, and coupled to the necessary piping. The set is controlled by a simple starting switch, and needs no attendance except for oiling occasionally. It is easy to apply automatic control to such a plant, so that it pumps water until a tank is full, and then stops working until the water-level again falls to a predetermined value. The only difficulty that may be met with is due to the need of priming; if the pump is full of air, it will not start lifting until it has been

filled with water. Hence a foot-valve must be fixed at the foot of the suction pipe, and kept in order, and means must be provided to prime the pump in the event of its running dry through leakage of the valve. It is also desirable to place the pump as near as possible to the level of the water in the stream or well from which the supply is derived. This, however, is not a serious matter,



Rees Roturbo Mfg. Co., Ltd.

FIG. 31.—ELECTRICALLY-DRIVEN CENTRIFUGAL PUMP.

and it is common to nearly all pumps, however they be driven.

The efficiency of a well-designed centrifugal pump is very high—60 to 80 per cent—which is much better than that of a plunger pump. Besides saving the cost of a tower for a wind pump, the electric pump is independent of the occurrence of calms, which may necessitate the provision of a high-level reservoir capable of holding a week's supply of water, and thus it is considerably

cheaper in first cost ; it is also cheaper in maintenance and attendance. A centrifugal pump cannot conveniently be driven by a windmill, which is therefore restricted to the use of the inefficient plunger pump. Moreover, a motor-pump will last for years, whilst a reciprocating pump is subject to wear and corrosion, which cause leakage. In some cases, however, it may be necessary to drive a reciprocating pump by motor ; this presents no difficulty, suitable reduction gearing being provided. Such a case occurs when water has to be raised from a well more than 25 ft. deep, as it is not desirable to fix a motor-pump below ground. Several ingenious devices of the chain-pump type have been developed for lifting water from deep wells without fixing a pump below ground, and these can readily be driven by electricity. Water can also be raised from a bore-hole only a few inches in diameter by the "air-lift" pump, which can be driven by electric power.

In California hundreds of thousands of acres of agricultural land in arid districts are irrigated by means of electric pumps, and the output of food products was enormously increased during the war, mainly by the use of this system. In this country rain is not so scarce, but in some districts irrigation is necessary, whilst in others drainage is equally needful, and for both purposes the electric pump is ideally adapted.

It is estimated that electric motors of an aggregate power of 200,000 h.p. are in use in the United States on farms, and that of this total no less than 160,000 h.p. is used for irrigation and the reclamation of desert lands.

Pumping Data. To raise 100 gallons of water per minute through a height of 33 ft. requires a net expenditure of 1 h.p. ; but owing to losses in the motor, pump, and pipes, at least double this amount must be supplied electrically. The work done in lifting water is measured in ft.-lb. by the product of gallons of water into the height in feet multiplied by 10, a gallon of water weighing 10 lb. Hence, in order to find the "water horse-power," the result thus obtained is divided by the time occupied in minutes and by 33,000. As already mentioned, twice this horse-power must be supplied to the motor, unless the plant is a large one—the best result, without allowing for loss of head in the piping, being about 73 per cent efficiency for a town supply.

CHAPTER IX

ELECTRICITY IN DAIRY AND POULTRY FARMING

Milking by Electric Power. We have already mentioned the use of electricity for milking cows ; this process is electrical only in that the milking machine is driven by a small electric motor. By no other means can the power be applied and controlled so conveniently, and it is one of the outstanding advantages of the use of electricity on the farm that it so greatly facilitates the adoption of mechanical milking, thus abolishing the open milk-pail with all its insanitary accompaniments, and ensuring the purity of the milk, besides immensely reducing the time and labour involved. A motor of 1 h.p. can milk five cows at a time, and one man can attend to three or four milkers. Milk being a fertile medium for germs, it is most important to shield it by every possible device from infection, but this cannot be accomplished where hand milking is in vogue.

At a Canadian dairy where electricity was freely used in 1913, it was found from records taken over six months that the energy consumed for milking cost one-sixteenth of a penny per cow, and for cream separating slightly over $\frac{1}{2}$ d. per hour.

According to Mr. L. Birks, electrical engineer to the Dominion of New Zealand, on April 30th, 1920, out of 35,643 milk-suppliers to the dairy factories, 8,806 were using milking-machines

requiring 2 to 3 h.p. each ; the demand for this purpose will constitute a large proportion of the total demand for electric power in the Dominion, and a revenue of £24 to £30 a year is derived from the average dairy farm for the milking-machine alone. Careful measurements have shown that the consumption of energy is from 25 to 30 kWh per cow per annum, but with efficient plant and good management much less energy suffices. Under the local conditions a suitable installation comprises an electric motor, vacuum pump, cream separator, water supply pump, and a 10-gallon hot-water cistern (electrically heated).



FIG. 32.—ELECTRIC MOTOR
DRIVING A CHURN.

Electrical Sterilization of Milk. In the dairy electricity finds employment in driving churns (Fig. 32) and cheese presses, refrigerators, and cream separators ; it has also proved to be an efficient means of sterilization without injurious effect on the milk, but this process has not yet become so well known as it deserves to be. At Liverpool University experiments have been in progress for some ten years, and it has been proved that whilst "pasteurized" milk is not completely

freed from bacteria and quickly becomes self-contaminated again, electrically sterilized milk

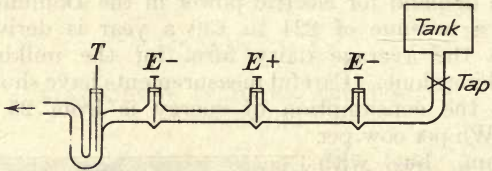


FIG. 33.—DIAGRAM ILLUSTRATING ELECTROLYTIC STERILIZATION OF MILK.

remains sound and sweet for several days, or even weeks.

The method illustrated in Fig. 33 consists in treating the milk with alternating current whilst

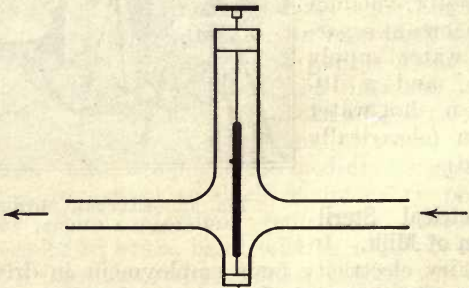


FIG. 34.—AN ELECTRODE FOR THE STERILIZATION OF MILK.

it is flowing slowly through a glass tube between copper electrodes (Fig. 34), maintained at a potential difference of 2,500 to 3,500 V. The passage of a small current through the milk raises its temperature to about 147° Fah., which

provides a convenient means of observing the operation of the apparatus; it is held that the heating plays no appreciable part in the process, as milk raised to the same temperature by other means is not sterilized. The untreated milk is poured into a tank, from which a second tank is fed through a ball-valve, so that the milk in the latter vessel is kept at a constant level and therefore flows through the apparatus at a uniform rate; after sterilization the milk is delivered into one or other of two tanks, from which it is run off into a main receiver, the use of the auxiliary tanks being to prevent any milk flowing directly into the main tank in the event of any failure of the apparatus. The connections are so arranged that no person can touch the "live" high-pressure terminal, and the milk both enters and leaves the apparatus at earth potential, so that the apparatus is absolutely safe to handle.

The treated milk is practically free from bacteria, but otherwise is not altered in any way, its taste being unaffected. The *bacillus coli*, a common infection, and the *bacillus tuberculosis* are completely destroyed, even in milk which is rich in these bacteria; the lactalbumin, which is coagulated in milk treated by the ordinary method of sterilization, and the enzymes, are unaffected by the electrical process. At Liverpool the experiments were so successful that plant was laid down by the Corporation at one of its milk depots for the treatment of milk on a large scale, over 100 gallons of milk being sterilized daily and distributed in bottles.

Besides the sterilizing apparatus, a small transformer is required to raise the pressure of the

alternating current to the necessary high pressure, and if the electricity supply is direct current, a motor-generator is used to convert it to alternating current, the Liverpool plant giving 2 A at 4,000 V, or 8 kW.

Another method of sterilizing milk is by exposing it to ultra-violet rays produced by mercury vapour lamps.

Incubation by Electricity. On the poultry farm, which, with the dairy, is usually under the control of the housewife, electricity can be applied to drive apparatus to mash potatoes, mix food-stuffs, etc. Its advantages are, however, more conspicuous in connection with the hatching of eggs, for which purpose it is ideally adapted. Being free from fumes and fire risk, and under perfect control, it is by far the best means for heating incubators. The heating appliance consists of carbon-filament incandescent lamps, which are extremely cheap and most readily inserted or replaced, while the incubating chamber is constructed of wood in two compartments, one above the other, the lower one containing the eggs and the upper one the heaters. A thermostat is placed in the incubating compartment, and is connected with the heating circuit, controlling the current so as to maintain a constant temperature of 103° F. in the chamber.

Mr. R. Borlase Matthews emphasises the importance of circulating the air in the incubator with an electric fan. He states that in his 2,240-egg incubator, thus equipped, the average proportion of fertile eggs hatched is 83·5 per cent. This incubator measures 5 ft. square by 32 in. deep.

Electrical heating is also particularly advantageous for brooder houses or foster-mothers.

A duck farm exists near New York, where some 20,000 to 25,000 ducks are raised yearly for table use by means of electric incubators having a total capacity of no less than 9,600 eggs. The heating lamps are connected to a circuit at a pressure of 10 V, so that fire risk is practically eliminated; this pressure is obtained from a transformer, the supply being alternating current at 110 V, but direct current could equally well be used, at any pressure up to 220 V, the lamps being connected in series if necessary to obtain the right resistance. The amount of heat required being small, the energy consumed is inexpensive; moreover, as it is a continuous load, and does not occur in the winter, it should be obtainable on specially favourable terms from a public supply system. At the duck farm above-mentioned, electric lamps are used to illuminate the farm buildings, and 20 bushels of green food are cut up twice daily and mixed with other food by electrically driven machines, for the 10,000 ducks, the mixer being in constant use. Two out of three pumps are also driven electrically, the third being wind-driven.

“ Intensive ” Egg-Production. Another use to which electricity can be put on a poultry farm is to stimulate egg-laying. It has been found by experiment that when the day is prolonged by the use of artificial light, fowls will eat more, take more exercise, and lay more eggs. Hence “intensive” egg-laying has been practised by providing electric light in the hen-run, during the season of short days, the cost being small compared

with the profits accruing from the sale of the eggs.

Under Canadian conditions, chickens hatched out with incubators before the end of March will lay eggs in winter, if provided with electric light. Experiments carried out at the Manitoba Agricultural College, Winnipeg, in 1919, proved beyond doubt that by this means an abundant supply of eggs could be obtained in winter when the price of eggs was at its highest. The lamps were used from dusk to 10.30 p.m., and from 7 a.m. to daylight. Mr. R. B. Matthews states that from 10 to 25 per cent more eggs can be obtained during the winter months at a cost for lighting of only $\frac{3}{4}$ d. per bird per annum.

The *electrical egg-tester* consists of a box containing an electric lamp, and having an opening rather smaller than an egg; when an egg is placed against this aperture, with the lamp alight, the interior of the egg is brightly illuminated, and it is easy to judge of its condition.

CHAPTER X

ELECTROCULTURE

Electricity and the Growth of Plants. For many years the idea of accelerating the growth of plants by electrical treatment has been the subject of experiment and more or less scientific research on the part of inventors, but the results on the whole have been disappointing. Of the numerous methods of applying electrification that have been tried, very few have shown any real promise, and only one has shown fairly consistent and favourable results, viz., that which makes use of a high-pressure electrical discharge into the air over the growing plants. During the past fifteen years a good deal of attention has been devoted to this process by a number of patient experimenters, and it appears to be certain that, other things being equal, the high-pressure discharge does increase the yield and hasten the growth of plants. The amount of the increase varies a good deal with the season's weather and with the mode of conducting the process, which is still in the stage of experiment.

The High-Pressure Discharge. This process of electrification of plants is known as "Electroculture," and is usually carried out by suspending over the young plants a series of parallel wires of small section, which are maintained at a pressure of from 30,000 to 60,000 V above earth potential. The treatment is applied for a few hours daily,

morning and evening. The fine parallel wires are supported by a stouter wire running along each side of the field under treatment, and attached to insulators on poles ; in some cases the network is fixed at a height sufficient to clear loaded wagons, in others it is only 5 or 6 ft. from the ground, so that it has to be removed before the harvest is taken, and in other experiments the network has been supported from the poles in such a way that it can be kept within 1 or 2 ft. of the tops of the growing plants throughout their development, and hauled up out of the way for harvesting. There is little doubt that the last-named method is the most effective. The network is very light and easily raised or lowered. According to Dr. C. Chree, uniform conditions at the level of the crop can be secured if the distance between adjacent wires does not exceed the height of the wires above the crops.

Preferably the charge is unidirectional, the wires being positive with regard to the earth, but in some cases alternating current has been used ; the latter is the easier to apply, the production of a continuous current at such high pressures presenting some technical difficulties, which however are not insuperable. In all cases the high-pressure current is obtained by means of a transformer in the first instance, being afterwards rectified. The first investigator in this country who obtained marked results was Sir Oliver Lodge, who used for the purpose of rectification a device known as the Lodge valve, which permits the current to flow through it in only one direction, and this system has been followed by most of the researchers. Another effective rectifier is that of Delon, which

employs a combination of condensers with a mechanical revolving switch of simple construction, and has been proved very satisfactory in operation.

When the process is at work, a slight hissing sound is heard from the charged wires, and at night they may be seen to glow faintly. The amount of energy used to charge the wires is very small, and the cost of the network is also very moderate compared with the results attained, while of course the apparatus can be used year after year. The operation of the plant is simple, and can be entrusted to any man of reasonable intelligence.

Results of Electrification. It will be of interest to quote some of the results which have been obtained in recent years, premising that in every case control plots adjoining the electrified areas, but not electrified, are sown with similar seed and serve for the purpose of comparison. In 1912, Miss E. C. Dudgeon, Lincluden Mains Farm, Dumfries, experimenting with potatoes, recorded an increased yield of 10 cwt. 3 qr. per acre; in 1913 the increase was 13 cwt. 3 qr., and in 1914 1 ton 3 cwt. It will be noticed that the increase is progressive, and it has been found that a plot which has been electrified in one year will again show an increased crop in the following year, although not then electrified, so that apparently some influence is exerted on the soil. In 1915 Miss Dudgeon grew oats, and obtained an increase of 31 per cent in the grain, and 63 per cent in the straw. Her theory is that under the influence of the electrical discharge, the ingredients in the soil necessary to plant growth are rendered more

soluble and more easy of assimilation ; that the sap is enabled to flow more vigorously, and the formation of starch and sugar is increased ; that respiration, absorption, and evaporation are accelerated, and by increased chemical activity in the plant its whole fabric is improved.

Official Trials. In 1916 further experiments were carried out on Miss Dudgeon's farm, under the observation of Prof. V. H. Blackman and Mr. I. Jorgensen, and were described in the *Journal* of the Board of Agriculture. The crop was oats, and the field had been in pasture without manure for three years. The network consisted of No. 24 S.W.G. bronze wires $4\frac{1}{2}$ yds. apart, supported at their ends at 7 ft. from the ground, and sagging to 6 ft. at the centre (the wires had been 10 ft. high in 1915, and 15 ft. in 1914). The current was 3 A at 50 V in the primary circuit, and the electrical discharge was used for 848 hours during the season, in the daytime. The result was an increase of 49 per cent in the yield of grain, and 88 per cent increase in straw, in spite of a heavy loss of grain through stormy weather. The increased value of the crop was calculated at £6 7s. per acre, whilst the energy expended cost 11s. at 1d. per unit.

Other Experiments. Some interesting experiments were carried out at Llantwit Vadre, near Pontypridd, in 1917 and 1918. The plant included a Delon rectifier, and maintained a pressure of 30,000 to 39,000 V on the network, according to the weather ; it cost £300, and was capable of dealing with 100 to 150 acres—say, £3 an acre.

The network was of galvanized steel wire, and cost (for 1.2 acres) about £12, or £10 an acre, making a total first cost of £13 per acre. The crop was potatoes, and increases of 17.2 and 12.6 per cent were registered, in comparison with control plots, the yield in 1918 amounting to 9.46 and in 1917 to 7.5 tons per acre. The duration of treatment was 282 hr. in 1917, and 588 hr. in 1918, and the current going to the network was 2.5 mA in 1917 (dry), to as much as 7 mA (wet weather); in 1916, with a different arrangement of the network, the current averaged 0.5 mA.

Many other records could be given, if space permitted, but we must be content with stating that many experimental installations have been set in operation, and the Board of Agriculture is conducting researches with a view to developing the system on scientific lines. The latest report of a committee appointed by the Board to investigate the subject states that the average effect of electrification on spring-sown oats and barley is an increase of 22 per cent in the yield.

The process is equally applicable to greenhouses, and in a number of market gardens it has been employed with success, tomatoes, cucumbers, strawberries, etc., being ready for market from two to three weeks before unelectrified produce, and commanding a correspondingly high price. The cost of an apparatus for four large greenhouses, 200 × 28 ft., including an oil engine, was £135, and the running cost was 2s. 6d. a week.

The Wolfryn Process. During recent years much has been claimed for a system of electrifying seeds before sowing—the Wolfryn process, in

which the seed is soaked in a weak solution of salt or calcium chloride, through which a current is passed for several hours, after which the seed is dried in a kiln. Large areas were sown with the electrified seed in Dorset, and the results obtained were said by many farmers to be quite comparable with those given above for electroculture. Reports of the Director of the Government Agricultural Experimental Station at Rothamsted, and by Messrs. Sutton and Sons at Reading, on trials carried out in 1919, were, however, unfavourable. While in both cases some tests showed a slight increase of yield, others showed the contrary, and the conclusion was that the process lacked certainty, and could not be compared in effectiveness with manuring the soil. It was regarded as an "adventure," which might or might not prove profitable. At the time of writing, therefore, it cannot be considered a sound process.

Amongst other methods of increasing plant growth, the use of artificial light has been tried, with the aid of electric lamps. By this means the rate of development is doubled, but the cost is considerable, and the process is suitable for use only under special circumstances (*see* Chapter V, p. 63).

Artificial Fertilizers. The use of chemical fertilizers is an indispensable feature of modern agriculture, and great quantities of "nitrate" are imported from Chile for this purpose, as well as various chemicals from other sources. In recent years great progress has been made in the production of nitrogenous manures, such as sulphate of ammonia, by the "fixation" of

nitrogen from the air by electrical means ; * this source of nitrogen is inexhaustible, and in certain districts where a cheap and abundant supply of electricity is available the fixation of nitrogen has become an exceedingly important industry. One process, in which an electric arc is employed, is comparatively simple and easily controlled, and it is confidently anticipated that at no distant date it will be possible for a farmer who operates on a fairly large scale to manufacture nitrogenous fertilizer with the aid of his own electrical plant.

* See also *Industrial Nitrogen*, by P. H. S. Kempton, uniform with this volume (Pitman, 2s. 6d. net) for a detailed treatment of the fixation of nitrogen and the applications of nitrogen products.

CHAPTER XI

THE HEREFORD DEVELOPMENT

Legislative Obstacles. Whilst in other countries the use of electricity in agriculture has been developed widely, in Great Britain it has made but little progress. Probably the chief reason for this backwardness is the fact that under the conditions which have hitherto obtained, a supply of electricity has rarely been available to the farming community. The legislative restrictions which have so long hampered the development of electricity supply in this country included the strict confinement of an ordinary statutory authority to set bounds, usually those of the town or urban district concerned, so that a farmer a few yards beyond the boundary could not legally be supplied with electrical energy from the town mains. Moreover, any attempt on the part of the authority to obtain powers to supply in adjoining districts was generally resisted by the authorities governing those districts, a short-sighted policy which can only be ascribed to jealousy, which was gratified at the expense of the unfortunate residents in the outer areas. The establishment of a Board of Electricity Commissioners, however, with the definite duty of taking measures to extend the supply of electricity throughout the length and breadth of the land, with a special charge to provide for the needs of agriculture, and with extended powers for that

purpose, has fundamentally altered the situation, and though the accomplishment of their task will occupy many years, the way is now clear to the desired goal.

Difficulties Overcome. In the meantime, the fact that where the will to overcome the obstacles is present, the way can be found, has been admirably demonstrated in a few areas, of which the most noteworthy is that of Hereford, an undertaking to which we have several times referred in the course of this work. For the remarkable progress which has been made in that quarter the credit must be given to the City Council, which owns and controls the electricity supply undertaking, and in particular to the insight and perseverance of the City electrical engineer, Mr. W. T. Kerr, M.I.E.E.* At first progress was slow, but by steady propaganda and educational effort Mr. Kerr gradually secured the confidence of the farmers; as soon as a few of them adopted electrical methods, and learned to appreciate the benefits they derived therefrom, others quickly followed, and the problem changed from a canvass for consumers to a search for plant to supply them.

Even before the war the agricultural supply had been developed and placed on a sound footing; indirectly the war gave it a marked impetus, for plant which had been installed for the manufacture of munitions of war was made available for the purposes of peace, partly by the assistance of the Development Commissioners, who learnt that a large number of farmers were anxiously waiting for a supply of electricity, with little

* Mr. Kerr resigned his appointment early in 1922.

prospect of its becoming available, the whole of the Corporation's resources being fully taken up. The Commissioners therefore made a loan to the Corporation for the purpose of securing the Government generating plant and devoting it to the supply of electricity over a radius of 15 miles ; thus, in effect, the swords were beaten into ploughshares.

Overhead Mains. The existing network of mains is chiefly overhead lines carried on wooden poles, the pressure being 11,000 V. Such a line costs at present prices £850 a mile. A heavy line is being erected on steel lattice poles, about 36 ft. high, with spans of from 320 to 350 ft. ; for a commencement the line will run out $10\frac{1}{2}$ miles, but later it will be extended to 16 miles. Wayleaves have been obtained without much difficulty, at a maximum rental of 1s. per pole per annum, mainly by the tact and persuasive powers of Mr. Kerr, who has secured wayleaves for a total of 65 miles of overhead lines and over 2,000 poles. The cost of the steel pole line is £1,805 per mile. Low-pressure lines (19·064") cost £300 per mile, very light larch poles being used, 40 ft. long, with the butts charred to prevent decay ; the low-pressure supply is three-phase at 400 V, and the line carries 60 kW and supplies up to a distance of three miles from the transformers.

System of Supply. There are in the Hereford district over 6,500 farms, which, if they used internal combustion engines for power generation, would consume, at 500 gallons each and 2s. 8d. a gallon, over £425,000 worth of petroleum per

annum. A farm of 100 acres consumes from 3,000 to 10,000 units of electricity per annum,* with a load factor of 20 per cent, and a high diversity factor—plant rated at 125 kW can safely be

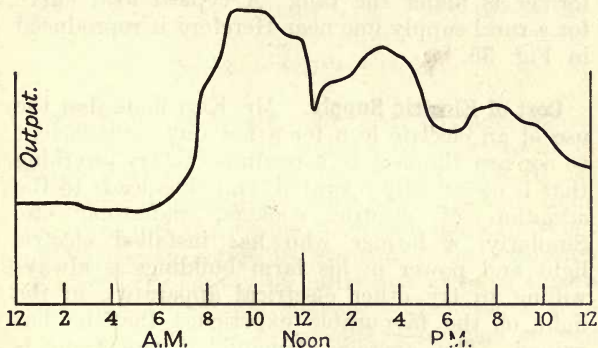


FIG. 35.—LOAD CURVE ON A RURAL SUPPLY LINE NEAR HEREFORD (6TH OCTOBER, 1920).

Supply-station engineers will appreciate the importance of the relatively heavy demand shown during the daytime.

supplied from a 25 kW transformer, the size found most suitable. Three transformer stations can supply low-pressure current to an area measuring 15 miles long by 6 miles wide. The transformers

* According to both Continental and British experience quoted by Mr. R. Borlase Matthews, the annual consumption of electricity in farm buildings averages 10 kWh per acre served by them. On a very up-to-date farm, ploughing would account for an additional consumption of 33 kWh per acre of arable land, and other operations such as cultivation, electric silage, harvesting, etc., would increase this to 44 kWh per acre. In the farm-house the consumption for lighting may be estimated at 200 kWh, and for cooking, heating, and domestic power at 800 kWh, per annum.

need not be placed in buildings, which are costly ; they may be mounted on poles, but usually a village requires a water tank fed by an automatic electric pump, and a good place for the transformer is under the tank. A typical load curve for a rural supply line near Hereford is reproduced in Fig. 35.

Cost of Electric Supply. Mr. Kerr finds that the use of an electric iron for a few days is sufficient to convert the user to a readiness to try anything that is electrically operated, and thus leads to the adoption of electric cookers, radiators, etc. Similarly, a farmer who has installed electric light and power in his farm buildings is always willing to try other electrical apparatus, in the light of the favourable experience that he has gained. The average demand of the farm is 15 h.p., the power being applied to pumping, pulping machines, etc., lighting, flat-irons, cookers, and radiators. The tariff is based on a fixed annual charge of £10 per kilowatt of average demand, together with a running charge of $2\frac{1}{2}$ d. per unit consumed, for the first 520 units per kilowatt, after which the price is reduced by half. An example of the application of the tariff is given below, for an installation of 20 lamps of 50 W each, two 1-kW radiators, one 4-kW cooker, and one motor of 8 h.p. used 2 hours daily. The average demand is 3.2 kW, and the consumption 5,000 units per annum.

The cost of lighting by electricity is found to be about one-third of that with petroleum, in addition to which there is a marked saving in painting and decoration.

	£	s.	d.
Fixed charge at £10 per kilowatt per annum	32	-	-
1,664 units at 2½d.	17	6	8
3,336 „ 2½d. less 50 per cent	17	7	6
Total	£66	14	2

Average price per unit, 3·2d.

The National Aspect. Mr. Kerr has pointed out that if the farmers are obliged to resort to oil or petrol for their motive power, the bulk of the agricultural machinery will be dependent upon imported fuel, the supply of which is liable to be cut off by enemy action in war-time; the extension of electricity supply to cultivated areas is thus a measure of national defence. The wages paid for agricultural labour nowadays are high enough to attract the best types of men and women to the land, if the living conditions are made cheerful and comfortable, a state to which the use of electricity is highly conducive. Some 2,500,000 acres of land went out of cultivation in 1920, and all classes of cereal crops are decreasing in volume, as well as the number of cattle and sheep; there is great risk to the national interests unless the migration from the land is checked.

For every horse that is displaced by the substitution of mechanical power, an outlay of £5 a week is saved, and three acres of land is set free for more efficient utilization. In France and Holland large sums are being provided by the respective governments for the purpose of supplying electricity in agricultural districts, owing to the improved results obtained by its use.

Canadian Developments. For many years the immense water-power resources of the Province of Ontario have been in course of development by the Hydro-Electric Commission of that Province which is charged with the duty of utilizing the Falls of Niagara and other rivers for the generation of electricity, and distributing electrical energy to the local authorities throughout the Province. Naturally, the Commission is deeply interested in the welfare of the farming community which forms so important a section of the industrial population of Canada, and has spared no effort to develop the use of electricity for all agricultural purposes. With this end in view, the Commission has periodically organized local exhibitions of apparatus for domestic and industrial use on farms, as well as travelling outfits for demonstrating the various applications of electricity in villages, etc. These propaganda efforts are fully described in the annual reports of the Commission, to which the greatest credit is due for its practical and intelligent policy. The travelling outfits are taken to farms and set in operation from the high-pressure transmission lines, and the amount of work accomplished, together with the energy consumed at each farm is published with comparative data showing the much greater cost of doing the same work by other means. The Commission also has in operation a number of demonstration farms completely equipped with electric power; accurate records of work done and energy consumed are kept, and the reports of the Commission are a mine of information on these points (*see Bibliography, p. 113*).

It is not only on farms within reach of the

mains, however, that electricity is used in Canada ; there were in 1920 from 8,000 to 11,000 farms in the Dominion with isolated installations, mainly driven by internal-combustion engines. This fact alone should serve to indicate the value set upon electrical methods of operation by the Canadian farmers, and there is no reason whatever why British farmers should not emulate their progressive policy, and "Do it Electrically."

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