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VI.

POWER

FOR CULTIVATION AND HAULAGE ON THE FARM

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VI. POWER FOR CULTIVATION AND HAULAGE ON THE FARM

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FOR CULTIVATION AND HAULAGE ON THE FARM

BEING THE REPORT OF A CONFERENCE HELD AT ROTHAMSTED ON FEBRUARY 9TH 1928 UNDER THE CHAIRMANSHIP OF

SIR MERRIK BURRELL, C.B.E.

With Contributions by

B. A. KEEN, D.Sc., F.Inst.P.; H. C. BURFORD, M.I.A.E., M.I. Mech. E.; G. W. WATSON, M.I.A.E., M.I.Mech.E.; E. PORTER, B.Sc.(Agric.); R. D. MOZER; R. BORLASE MATTHEWS, Wh.Ex., M.I.E.E.; and others

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CONTENTS

PAPERS

HORSE AND MECHANICAL POWER IN FARM OPERATIONS

By B. A. KEEN, D.Sc., F.Inst.P.
Assistant-Director Rothamsted Experimental Station

The advent of mechanical power on the farm began in the middle of last century, when steam-power was first applied to cultivation. The agricultural Press of that period—particularly the *Journal of the Royal Agricultural Society*—bears much evidence of the high hopes entertained for this innovation. The enthusiasm was not without reason, for everything pointed to a long period of abounding prosperity in agriculture; in fact, the decade 1852-1862 has since been known as "the golden age of English farming." It was succeeded only too soon by the great depression that began in the late 'seventies, and it is significant that steam cultivation weathered this period of stern trial, and still remains to-day an established practice. But its struggle for survival clearly showed that its true position was an adjunct to, and not a substitute for, horse labour. Steam-power came to stay as a valuable aid in rapidly breaking heavy land in the autumn, and for deep spring cultivation—especially for crops like potatoes, that respond to a deep tilth.

In more recent years the internal-combustion engine has rapidly extended into agriculture, and the situation that arose when steam-power was introduced has emerged again, only in an intensified form. In the first place, the petrol or oil engine is a lighter unit than steam tackle; it is thus more comparable to the horse for ordinary farm work, and its cost permits the average farmer to purchase it, whereas he must put his steam work out to contract, with the risk that it will not be done at the most convenient time. In the second place, the internal-combustion engine has revolutionized road transport and haulage methods, and may do the same for farm haulage.

The latest information shows that the use of power for all purposes is steadily, or rather rapidly, increasing on the farm, in spite of the great depression of the past years: the extent can be seen from Table I., taken from *The Agricultural Output of England and Wales*, 1925, published in 1927 (Cmd. 2815. H.M. Stationery Office).

TABLE I

NUMBER OF AGRICULTURAL ENGINES RETURNED AS USED IN:

	1908	1913	1925
(a) *Fixed or portable*—			
Steam	8,690	7,719	3,731
Gas	921	1,287	1,125
Oil or petrol . .	6,911	16,284	56,744
Electric . . .	146	262	700
(b) *Motor tractors*—			
Field work . . .	...	...	14,565
Belt work (only) . .	...	...	2,116

The returns were voluntary; it is estimated by the Ministry of Agriculture that these represent about 75 per cent. of the engines in use. The increase in petrol engines is very great, and is far more than the decrease in other forms. Again, there were too few tractors to be recorded in 1913; in 1925 there were more than 16,500. It is evident that the internal-combustion engine has come to stay in agriculture, and our task in this Conference is to discuss to what extent it seems likely to replace horses, and to outline, on the basis of our present experience and information, those directions in which further improvements are needed.

The subject is twofold; it involves both technical and financial considerations, and, although they are so closely interwoven in practice, it is better for discussion to separate them as far as possible, and to take the financial side first. We have much information in our own farm records at Rothamsted, that Mr Garner has kindly summarized for me, and various departments of agricultural economics in the country have willingly given me additional data from their own detailed costings investigations.[1] The figures are in general agreement, and may be taken as reasonably close estimates of the costs of tractor and horse operations on the typical mixed farms where the arable area is not less than 40 per cent. of the whole, and is usually more.

Before considering the costs of different operations—*e.g.* ploughing and cultivating (with either the horse or the tractor)—it is desirable and instructive to see the general average cost for all work with each form of power. We will take horse-power first. In theory

[1] My thanks are due to Messrs King (Edinburgh), Thomas (Reading), Venn (Cambridge), and Wyllie (Wye), for help and information.

this is simply obtained; it is only necessary to obtain the total yearly cost of food, depreciation, shoeing, veterinary service, etc., less a credit for manure produced, and to divide this by the total number of hours that the horses worked, to arrive at the cost of a horse-hour. In practice the estimation of this figure is not so simple, as there are many interlocking costs, the fair apportionment of which is difficult, if not impossible. For this reason the practices of economists engaged in agricultural costings vary. In some cases "stable labour" is not charged; in others, depreciation and repair of implements is not included, and so on. The figures in Table II. have been obtained from several sources, and modified to bring them as far as possible to a common basis. They are the averages for a small number of farms in each case.

TABLE II

COST PER HORSE-HOUR IN PENCE, EXCLUDING IMPLEMENT DEPRECIATION AND REPAIRS

Year	*Rothamsted*	*S.E. England*	*Eastern Counties*
1923-1924 .	7·75[1]	5·11	4·62
1924-1925 .	...	5·33	5·08
1925-1926 .	6·75	5·56	4·94
1926-1927 .	...	...	5·95

These figures refer to widely different soil types and cropping systems, but are sufficiently close together to make the average of some significance. The somewhat high figure for our own farm is explained by the presence of several hundred experimental plots. Although the accounts for these are kept separate from the normal farm operations, they have to be worked by substantially the same staff and farm equipment. This arrangement is both inevitable and costly, not only for the experimental plots but the rest of the farm, and it is surprising that the figure is not much higher.

The original figures for the Eastern Counties included implement repairs and depreciation, and as the cost of this was not given separately, the round sum of 3d. per horse-hour was deducted to give the values in Table II.; our own figure was 3·44d., and seemed rather too high.

It appears, therefore, that a fair average cost per one horse-hour is about 5¼d. This figure includes cost of food, less credit for manure produced, cost of shoeing, veterinary service and medicine,

[1] Includes much hired horse labour, which is notoriously expensive.

harness repairs and depreciation, attendance, depreciation on the horses; it does not include implement repairs and depreciation, certain overhead charges on buildings and managing expenses, and of course the man's wages are excluded except that portion coming in under attendance charges.

The next step is to obtain a similar figure for the tractor, and this is more uncertain, as few costings have yet been made. In Table III. are some collected results.

TABLE III

COST PER TRACTOR-HOUR, EXCLUDING IMPLEMENT DEPRECIATION AND REPAIRS

Year	*Rothamsted*	*S.E. England*
	s. *d.*	*s.* *d.*
1922-1923	3 6½	...
1923-1924	5 5	3 2
1924-1925	3 3	2 8
1925-1926	3 3	3 1
1926-1927	3 3	...

These figures include tractor depreciation, fuel and oil, repairs, and a few sundries, but do not include implement depreciation and repairs and driver's wages, except in the Rothamsted figures, where the commissions paid to the farm-hand acting as tractor-driver are included, and amount to just 10 per cent. of the total cost per tractor-hour.

A figure of 3s. per tractor-hour is probably not far away from the average cost, although in the figures from which Table III. was constructed there were, just as in Table II., very wide variations in cost from farm to farm.

However, on a reasonably equal basis of comparison, we may say, with fair accuracy, that a horse-hour costs 5¼d. and a tractor-hour, 3s., —or nearly seven times as much—and to this must be added the difference between the hourly rates of wages for horsemen and tractor-drivers.

This comparison is based on the total work of all kinds that the horse and the tractor perform on the farm, and too much weight must not be placed on it. It has been arrived at by a drastic process of averaging, and it includes not only widely different types of work but different systems of agriculture, and varying degrees of skill in management. Still, as a general over-all figure, it gives some precision to the comparison of the two forms of power.

The next information desirable is the relative costs of tractor and horse for the same kind of work. A certain number of comparisons for work on the same farm are available. These are collected in Table IV. on a basis of costs per acre, and include also some tractor figures for which horse-figure comparisons are not available.

TABLE IV.

COST PER ACRE FOR HORSE AND TRACTOR, INCLUDING WAGES

	Rothamsted	*South East*	*East*	*South West*
Ploughing—				
Horse . .	20/-	19/10, 14/10, 17/2	...	...
Tractor. .	15/9	14/6, 11/11, 8/-	13/7	(18/5), 11/-
Cultivating—				
Horse . .	2/6	4/	...	...
Tractor. .	3/6	4/5	3/6	...
Harrowing—				
Horse . .	1/6			
Tractor. .	3/6			
Rolling—		...	2/7	...
Horse . .	1/6			
Tractor. .	2/1			
Harvest—				
Horse . .	2/7	2/8, 2/1	...	...
Tractor. .	3/11	3/6, 4/7¼	4/3½	...

Here again, although there are appreciable variations, the general run of the figures is sufficiently close for our purpose, and we may now proceed to discuss the bearing of these costings figures on the technical and practical questions.

The first question that arises is an obvious one: Is the tractor likely to replace the horse as the main source of power in British agriculture? At first sight it appears equally obvious that the answer is a definite negative, since from Tables II. and III. we have seen that a tractor-hour is seven times more costly than a horse-hour. But the question is not so simple: the cost per hour is decreased if the number of hours worked is increased. At present the tractor on the average farm is used for 300 to 700 hours per year, while the horse puts in at least 1700; so there is ample opportunity for reducing the cost of a tractor-hour, if the practical

problems of using the machine on the farm to a greatly increased extent can be solved. In addition to this there is the certainty that the present-day running costs of a tractor will be reduced by improvements in design and by better care of the machinery. The distribution of the charges over the various items shows that, at present, fuel and oil account for about 50 per cent. and repairs and depreciation for 50 per cent. Beyond remarking that this indicates the responsibility for improvement, which lies equally on the manufacturer and the user, we shall not discuss it further, as other papers will deal with both these matters in detail. However, the improvement already achieved is shown by the two figures for S.W. England in Table IV. These were obtained on the same farm. The higher cost (in brackets) refers to a tractor working during 1922-1925, and the lower cost to a present-day model.

The second question that arises is: Assuming that the tractor is to be used mainly as an addition to horse labour, in what direction can it best help? Table IV. gives important information: the costs per acre in ploughing are appreciably cheaper with the tractor than with horses. In all other operations the tractor is dearer, but it need not necessarily be so. Ploughing is cheaper because the tractor is working at or near its maximum capacity, while in the other operations its load is too light. Until some mechanical genius builds an extensible tractor on the "unit" principle we must aim at increasing the load. The farmer can do this to some extent with his existing implements. Two binders can be hauled in tandem, harrows can be hitched behind cultivators—if the condition of the ground permits—and so on. But these are makeshift arrangements, for the setting of the front implement has often to be altered because of the drag behind it, and a wider headland also is needed for turning. There is scope here for the implement maker.

Up to this point we have based the comparison of horse and tractor work entirely on costs of operations. But the great advantage of the tractor is its power and speed, and its ability to work for long periods. It enables rush periods to be dealt with so that the work can be kept well ahead. The results are reflected in the final yield and the financial returns, but it is almost impossible to manipulate the figures to show the part played by the tractor. Unfortunately, in our climatic conditions the farmer knows only too well the results of a short enforced delay at a critical period, and has no doubts whatever about the advantage of being well ahead with his work.

This aspect can best be seen by taking a few typical examples:

(a) *Autumn Cultivation in Dry Weather.*—The important operation of stubble-breaking in these conditions often necessitates adding extra horses to the team, thus slowing up the harvest and carting. The tractor easily deals with the work.

(b) *Autumn Cultivation in Wet Weather.*—On heavy land in a wet autumn speed is essential if the work is to be done before winter sets in. The tractor can work the binder at high speed and for long hours, setting free horses for carting and cultivations.

(c) *Spring Cultivation.*—After a wet winter, and in a rainy spring, the intervals between a sodden state of the soil and a condition too dry for proper working are very short, and considerable areas have eventually to be pulled down into a "forced" tilth. The tractor can cope with the rush of work, thus increasing the area of land in good tilth.

Many other instances could no doubt be mentioned, and, when it is remembered that these advantages are also given by a machine that on heavy work compares very favourably with horse costs, a strong case is made out for the employment of a tractor on the average farm.

In addition to cultivation and harvesting work, the use of mechanical power on the farm will certainly increase. This is especially true of general haulage work, both on and outside the farm. The actual costs of this work can be well illustrated by a recent example. An Eastern Counties farmer has kept careful figures, and finds that collecting sugar-beet off the field, carting on main road to a station one and a half miles away, and unloading into trucks, costs him about 4s. per ton. If there is any congestion at the station the cost rapidly increases, and may reach easily 8s. per ton. In addition to this he loses the use of his horses for other work for three of the most important months of the year.

Some form of tractor that will pull larger loads at a greater speed than horses is a self-evident alternative. This implies some easily fixed form of road-bands for the wheels or, alternatively, easily removable strakes. Increased speed is also desirable, not only for road work but for cultivations as well. We have shown at Rothamsted that the soil resistance increases only slowly for a considerable increase in speed of working. Hence, there would be a further economy in land work if the tractor were designed to run at increased speed. Obviously some other factor might have to be sacrificed, or reduced, and the designer would have to make the best compromise, remembering that a working speed undesirable on purely technical grounds may have very distinct practical value.

Any advance of this nature also concerns the implement makers, since the proposed speed of an implement is one of the many factors to be taken into account by the designer. In fact, the general problem of tractor-implement design and construction —at first necessarily an adaptation of existing horse implements— can hardly be regarded as solved. They are designed largely

as separate units to be hooked on to the draw-bar; they are merely drawn by, and in no sense an integral part of, the machine. There is scope here for improvements, and at least one form of plough is now on the market designed for coupling direct on to a tractor. The advantages of easier control by the driver, ability to do neater work, and saving of space at the headlands would be fully appreciated by the farmer.

It is but a short step in theory from a series of cultivation implements that are definite attachments to the rear of a tractor to a single tillage machine that will produce a tilth at one operation. Much work is being done on rotary cultivation in an endeavour to solve the many practical problems of soil tilth. We shall not deal with this; it is the subject of another paper to-day, and our own experiments have already been discussed by the writer at an earlier conference on Cultivation. One aspect, however, must be mentioned. A rotary cultivator and its engine form a single machine, and although it could do belt-work also, it could not in its present design perform haulage work, and serve as a general-purpose machine to the extent that the tractor does.

The directions in which mechanical power will extend on the farm in the immediate future are unmistakable, and the salient features of the machine and its accessories can be written down: a tractor of 10-20 or 15-30 h.p., weighing about 30 cwt., fitted with a belt pulley and a power take-off for direct driving of binder machinery, etc.; a range of cultivation implements, not simply hooked on the draw-bar but properly coupled and closely under the driver's control; the maximum speed consistent with reliability; strakes easily and quickly removable, or covered with a band for road work (or possibly some form of caterpillar tread); and, finally, general reliability and a long working life.

To use such a machine to the best advantage is the farmer's task. He must give it the same attention bestowed as a matter of course on his horses. He must so arrange his horse and tractor work that each gets the type of labour for which it is best fitted, and, above all, he must exploit to the full the capacity of the tractor to do heavier work than horses, at a greater speed, and for a longer time.

Finally, investigation is urgently needed on such matters as deep ploughing, subsoiling and rotary tillage. The tractor has placed the means of doing these operations at our disposal, but we have very little information indeed about the best methods of doing the work, the most suitable designs of implements, and, above all, of the effect on the soil—which, after all, is the most important thing. This forms an important part of our work at Rothamsted. We are studying in the laboratory and in the

field under practical conditions the problems of soil tilth, on which developments of the above nature must be based.

In this brief review of the subject the endeavour has been made to compare and contrast horse and tractor work on the basis of actual performance alone, and the evidence leads to the definite conclusion that mechanical power will, on its merits, play an increasing part in our farming operations.

There are two other factors that will in all probability accelerate this process.

The first is: market for draught horses is rapidly diminishing with the greatly increased use of motor transport, and we seem to be within reasonable distance of the time when the farming community itself will be the only buyers of horses.

The second point is perhaps more debatable, but one wonders whether the traditional method of meeting bad times by taking land out of cultivation and laying it down to grass is going to survive the great development of the cheap imported-meat trade. Farmers met the competition of imported wheat in the 'seventies by laying land down to grass; they may be compelled to meet the competition of imported meat by maintaining their land in arable crops, in which prominence will be given to semi-market-garden crops, for which there is, throughout the country, a large and increasing demand.

THE DESIGN OF A GENERAL-PURPOSE TRACTOR

By H. G. BURFORD, M.I.A.E., M.I.Mech.E.

S. Hampstead

Before dealing with details bearing on the subject of the "General-Purpose Tractor," I think it would be of value to review the development of the Tractor industry that has been steadily taking place during the last two or three years. Unfortunately for all interested, the agricultural industry in this country has gone through very difficult times, and the general position is one of great anxiety. Whilst countries on the Continent are steadily developing the use of the tractor—covering very wide fields of activity, and absorbing them in large numbers—the home requirements are very small and, again unfortunately, supplied very largely from foreign factories. This state of affairs is very regrettable, and when the demand comes from the British agriculturist—as it is bound to do—Britain will

find great difficulty in meeting that demand. In my opinion—which has not changed for many years—the way to restore prosperity to the agricultural industry must be by the employment of mechanized power for every possible requirement on the farm. This opinion is based on the first and important question of *time*, and the necessity —owing to the various climatic changes—of using every available opportunity for intensive cultivation.

The manufacturers of tractors in the past have been met always with the question of producing tractors at a low price, and in many cases to meet these conditions it has necessitated the employment of unsuitable material, with results quite frequently very unsatisfactory to all concerned.

It has been found by experience that to give satisfaction it is imperative that material of the highest quality only should be used.

Assuming that the tractor of to-day embodies high-grade material, with all the advantages of heat treatment and the results of steel research derived from experience gained both during the War and after; and remembering that many manufacturers of tractors are also manufacturers of cars and commercial vehicles, and with their extensive production methods and modern machinery can bring into the tractor business their experience, thereby reducing the cost to a minimum; whilst other firms specializing on the production of tractors in specially equipped shops also have practical experience in productive methods in other branches of their business; based on these facts, the agriculturist, when purchasing a tractor, can be assured that all the ingenuity and skill of the engineer, both as to material and workmanship, are embodied in their latest products.

The question of maintenance and upkeep is being separately dealt with by Mr Watson, so that my remarks will be brief. The extreme conditions under which the farm tractor has to perform its work calls for care and attention from the hands of the user: cleanliness, care of entire lubrication system, periodical inspection and adjustment of all wearing parts, careful attention to all the instructions issued by the manufacturer, and good housing accommodation. Neglect of all or any of these points will be costly, and the results will be dissatisfaction to both user and manufacturer.

Practical experience and study have proved that the worst enemies to the agricultural tractor are dust, grit and lack of attention. Manufacturers are giving great care and study to eliminate the foreign matter from the engine. Not long since it was the general practice to take the air in through the carburettor by means of an open pipe; this led to excessive engine wear. Many devices have been tried, including water filters—*i.e.* the air being sucked through a volume of water. This, however, was unsatisfactory from many points of view, and has been discarded. Trials have

been made with an apparatus fitted with felts of various dimensions and sizes; this system failed for the reason that the operator did not change the felts often enough, and the finest particles were drawn through into the engine, naturally causing great damage. One leading manufacturer of to-day still retains the felt cleanser, but of generous proportions, owing to the position of the radiator. It is realized by experience, which has been gained in countries in Europe where conditions of long periods of drought exist, that to make a tractor at all practical and efficient an air clarifier and oil clarifier are indispensable. The present practice is for an apparatus to be fitted that can be removed easily and cleaned, and in which the air passes over or through a series of plates that have been dipped in oil. At the beginning of each day's work the plates—which are in the form of a cartridge and easily removed—are washed out by paraffin; they are again immersed in oil and replaced. This operation takes very little time, but the results in the reduction of wear on cylinders, pistons and other working parts are remarkable, and will give a much longer life to the most important part of the tractor—the engine.

Another important feature is the filtering of the lubricating oil from the sump of the crank-case. The oil passes through a filter, fitted with felt pads or coils. In this way the oil is cleaned of all foreign matter before being again pumped through the main oil channels. The results of this system add longer life to all wearing parts.

General-Purpose Tractor.—In laying down a definite specification for the above tractor, consideration must be given to the various conditions and requirements that are met with in the various parts of the world; and it is only by close study and careful analysis of these conditions that I am endeavouring to outline what in my opinion a tractor should embody to serve a useful purpose in the agricultural world. The tractor for general purpose on the average farm, in my view, should be of the light type—22 to 30 horse-power, at revolutions not exceeding twelve hundred per minute; four cylinders; good, strong and efficient radiator; gear drive fan and water pump; governed engine; magneto ignition; forced lubrication; crank-case to be of strong design; easy access to all parts requiring adjusting; ball-bearings to be made as dust-proof as possible; two speeds and reverse; all gears to be machine-cut and of highest-grade material, heat treated; rear axle to be of strong design; ample brakes to be fitted on rear wheels for use when on road haulage; weight not to exceed 30 cwt.; to have belt-power and speed capable of driving full-sized threshing-machine or any other implements used on the farm; adjustable draw-bar; facilities for changing spuds or strakes quickly and replacing with solid twin-tyres on rear wheels, single on front without change of wheel; to

be fitted with an air clarifier and oil filter; the front axle to be sprung and pivoted, capable of movement to accommodate wheels on irregular surfaces—in general, a tractor that can be operated easily, economically, and be capable of use for all the various requirements of farm work in general.

There is, of course, a field for tractors of a large horse-power and of a heavier type, but a tractor on the above lines will be found quite sufficient for the average requirements of the agriculturist.

Implements for use with the Tractor.—There is still much to be desired in the question of co-ordination of interests between the implement manufacturer and the tractor maker. At a very important demonstration under the auspices of the French Ministry of Agriture, in October 1927, it was observed that where the implements were doing bad work the blame was put on the tractor, and it was at once condemned. Whereas, actually, the tractor was performing its function of drawing the implement, but the implement was totally unsuitable for the work it was called upon to do. Developments of improved ploughs for tractor use are taking place in France and Germany. The advantages are many: ease of control; mounting close to and integral with the tractor; automatic self-lift; one-way operation; and over-all length of tractor and plough reduced to a minimum.

A few figures of the growth of the tractor use in America since the War may be of interest. The figures below are taken from an official statement made to the Pennsylvania College of Agriculturists:

In 1924 there were in use in that state 18,467 farm tractors and 452,000 horses. Assuming 1 h.p. for each horse and 10 h.p. for each tractor, the horse provided 71 per cent. of the draw-bar horse-power, and the tractors only 29 per cent. The figures given for 1924 compared with 1920—for tractors—show an increase of 224 per cent., as in 1920 the numbers stated to be in use were approximately 5697. The official statement also quotes that savings were effected by the use of tractors, the cost in ploughing being 1 dollar 75 cents. per acre. Given a ten-hour working day the tractor will plough approximately five acres, where the work done by a pair-horse team is approximately two acres. Cotton growers state that on a two-hundred-acre plantation the cost of the tractor can be saved in one year as compared with similar work done with a four-horse team.

In conclusion, it is of the highest importance for the future welfare of this country that every help and encouragement should be rendered to the agriculturist to use mechanical power on the farm. The modern tractor can and will do the work required at lower cost, saving of time, and with increase of crop. In the interest of British agriculturists I trust that the responsible authorities

will give a strong lead to the extended use of the tractor in this country, which will restore the agricultural industry to its right and proper position and so benefit the community at large.

THE CARE OF THE TRACTOR ON THE FARM

By G. W. WATSON, M.I.Mech.E., M.I.A.E.
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An agricultural machine or implement usually suffers from the simple fact that it is an inanimate object—*i.e.* it is without life or soul. Whilst most owners will give some measure of personal attention to even the meanest and least profitable animal on a farm, there are many who, having bought a machine, turn it over to a heavy-handed individual who has no knowledge of its construction, no interest in its success, and little or no inducement to acquire that knowledge or stimulate an interest.

Tractors may be divided, roughly, into two broad classes—firstly, the petrol or paraffin class; and, secondly, the steam class. I propose to confine my remarks to the former.

If an engine starts up at the first swing and runs with a healthy purr, indicating that all is well, a driver feels that he has made a good start for the day. This feeling of satisfaction is amplified if the engine answers to the throttle, and pulls in the field as though it took a real interest in its work. In the case of an engine that has been in use for any length of time these results are not obtained without trouble, but it is surprising how long an engine will keep in good condition if it receives consistent attention, and all adjustments are carried out as soon as they become necessary. Apart from the actual breaking of a vital part the diseases from which an engine suffers can be classified, roughly, under the general name of troubles, as follows: ignition, fuel supply, lubrication, valves, and water circulation. To this list of evils may be added knocking or noisy sounds, which are not evils in themselves but are simply warnings that all is not well.

Ignition.—It is of vital necessity to keep the coil or magneto free from damp, because if the condenser becomes damp it will not only cause leakage and failure of the ignition but will not hold any charge, and the resulting spark will not be efficient. Great care should always be taken to avoid spilling water over either coil or magneto, and should any be spilt thereon it should at once be

mopped off, and, if necessary, dried off by warm air from a lamp or stove, but care should be taken not to raise the temperature of the part so much as to melt the wax or shellac insulation.

I will now deal with some of the more common troubles experienced with ignition systems:

Misfiring.—The driver who knows his engine occasionally detects an alteration of its note or an interruption of its regular hum. This, if accompanied by a falling-off in power, is probably due to occasional or persistent missing of one of the plugs. When compression taps are fitted it is easy to locate the faulty plug. If all the plugs are firing badly, the fault may be either in the petrol supply or in the ignition. If only one plug is missing, the trouble can at once be set down to ignition alone, or, on rare occasions, to a valve being stuck open.

Faulty Plugs.—Apart from actual damage to a plug by breaking the porcelain or other insulation, there are three main evils from which it may suffer. Short-circuiting may take place between the points and the body, due to the hot spark having melted the metal. The gap of the plug may be too wide; it should not be more than about $\frac{1}{50}$th of an inch, or, roughly, the thickness of the average thumb-nail. If the engine misses when running at small-throttle openings the points of the plugs should be set a little farther apart, whereas, if missing takes place at full-throttle openings the points should be set closer together. The third evil is due to sooting up, and is cured by cleaning with a little petrol.

An occasional cause of missing is through having the points set in a pocket in the valve cap. This pocket remains full of spent gas left during the exhaust stroke, and a considerable improvement can be obtained by fitting plugs with a longer reach.

The Magneto.—The magneto may be the cause of irregular firing in any or all of the cylinders, but tampering with a magneto is a pastime not to be recommended unless a driver understands it. There are two points, however, to which occasional attention is required, these are the high-tension distributor and the contact breaker. This distributor disc should be cleaned occasionally with a cloth and a little petrol, and the disc wiped over afterwards with a trace of oil. The contact breaker is the most important part of the mechanism. The space between the platinum points when they are separated should be about $\frac{1}{64}$th of an inch, and any variation from this may cause ignition trouble. The contact points should be trimmed when necessary with a very fine file, so that they bend together level when closed, but they should not be trimmed unless the points are uneven. Oil should not be put on the platinum contacts, or it will cause them to burn away rapidly, Occasionally the lever to which the moving point is attached works stiffly, allowing the points to remain apart; in such a case the fibre bush should be

eased slightly. Oiling is of no use, as it may make it swell more. If these various points receive proper attention, there is little to go wrong.

A few warnings concerning magnetos:

Don't run the engine with a plug wire disconnected—you may ruin the insulation. If you want to cut out a cylinder, short-circuit the plug—that is, connect it directly to the metal of the engine.

Don't swamp the magneto with oil—two or three drops of good oil once a week are sufficient.

Don't oil the contact breaker.

Don't use an oil-can with dirt on the spout.

Don't file the contacts more than is absolutely necessary.

Don't hold the contact breaker to prevent the spindle turning when tightening up the nut of the driving coupling.

Don't fail to see that the earth wire is not making a short-circuit.

Don't hang plug cables on the exhaust pipe.

Don't replace plug wires on the wrong terminals.

Don't tamper with a magneto unnecessarily.

Motor Fuels.—Every driver knows that if petrol is poured on the hand it evaporates with a marked cooling effect, due to the petrol extracting heat from the hand. In a carburettor, fuel is supposed to be split up into a fine spray, and the heat for its vaporization is extracted from the air. Any cracks or leaks in the pipe which heats up the air to the carburettor should be repaired at once.

The jets in a carburettor are usually very small, and it is very necessary that all the fuel should be carefully filtered before it is put into the tank; as an additional precaution there should be a filter between the tank and the carburettor. These filters should be cleaned regularly, and any drops of water found therein carefully blotted up.

"Popping back" into the carburettor indicates a weak mixture, and is one of the first symptoms of fuel-supply trouble. Such a mixture burns slowly, and may still be burning when the inlet valve opens, thus allowing some of the burning gas to rush back into the carburettor. If the engine has been running normally and popping suddenly develops, look for some stoppage in the fuel supply. First try the float needle, and if the petrol does not flow into the float-chamber, although there is plenty in the tank, there is undoubtedly a stoppage in the pipes or the filter, both of which should be thoroughly cleaned. Such stoppages are frequently caused by small particles of scale from the tank, pieces of waste or fluff, or by drops of water which will not pass through the filter or the jets. Many engines have a tendency to pop back when

first started, from cold, but work satisfactorily after they have run a little time and become warm. The explanation of this has already been given in the paragraph dealing with hot-air supply.

Occasionally a float sticks, or is held up by grit, or the needle becomes bent or jammed, causing the carburettor to flood. Flooding may also result from a punctured float, in which case the petrol can be evaporated and driven off by immersing the float in hot water, and at the same time the issuing bubbles will show the position of the hole, which should then be soldered neatly, or, in the absence of solder, a temporary repair can be made by wiping a piece of soap over the hole.

A leaky joint in the inlet pipe may cause much trouble by weakening the mixture, and in an old engine leakage of air along the valve stems, due to wear in the guide, may have the same results. All joints should therefore be kept tight and leakages stopped as far as possible.

Very briefly, fuel-supply troubles and their remedies may be summed up as follows:

Engine pops back and stops: no petrol in tank, petrol pipe choked, filter stopped up, or water in petrol.

Engine pulls badly on hills: insufficient heating, or jet too small.

Engine flabby and exhaust offensive: jet too large, causing rich mixture.

No acceleration and engine staggers when throttle is opened: engine cold, or mixture too weak.

Carburettor floods: needle valve sticking, dirt under needle, valve or float punctured.

Consumption excessive: engine or transmission in bad condition, jet too large, ignition retarded, leakage of petrol, or brakes binding.

Let me here give a word of warning to drivers. A carburettor is a delicate piece of mechanism, but if properly fitted and treated carefully it rarely gets out of order. No driver should be misled by an engine knock to believe that there is something wrong with the carburettor, as under no circumstances can this be the case. Again, many drivers always blame the carburettor if an engine suddenly heats up, whereas the probable cause is that the fan belt is slipping, that there is no water, that the water-jacket is choked up, that more oil is needed in the crank-case, or because the ignition is retarded too much. Overheating is never caused by too much gas.

Lubrication.—Lubrication means the introduction of a separating film of oil or grease between two parts of a machine which have movement one upon the other. If the moving parts make actual

metallic contact the surfaces will soon become roughened to such an extent that they may seize. The higher the speed of rubbing the sooner seizure will occur, and its consequence will be more serious.

Some parts of motor vehicles are designed so as to create friction, but such parts are few, and are for special purposes—such as the main clutch, the brakes, the fan belt and the tyres.

Of all the sources of friction in an engine, that of the piston against the cylinder wall is the largest item, and is double or treble the total friction of all the other parts of the engine put together.

Valve Troubles.—Valve trouble is usually indicated by a gradual falling off in power. On examination the valve faces will be found scored and pitted, and it is necessary to grind them down on to their seats to again produce a clean face. If the face is very deeply pitted, it may be necessary to clean it up in a lathe, after which it should be ground to a true bed on the seating. In an old engine the seatings themselves may become rough, and necessitate truing up with a special tool, or, if not too bad, an old valve can be used for this purpose with a slightly coarser grade of emery, finishing off with fine emery and the proper valve.

The operation of grinding is a perfectly simple one, but requires to be done with care. Only the very finest flour-of-emery powder, mixed with lubricating oil to form a thin paste, should be used. This should be spread evenly on the valve face, and under a slight pressure the valve turned first in one direction, then in the other, occasionally lifting it and turning it through about half a turn before letting it drop on the seat again. This is to prevent the emery getting into tracks. If a light spring is slipped under the valve head, and is long enough to lift the valve from its seat, it will be found a great convenience, as on relieving the grinding pressure the valve will be lifted and it can then be twisted as much as is necessary before pressing down again. The exhaust valves suffer most, due to the hot gases sweeping across their faces, and it is for that reason that one usually allows a little more clearance for the exhaust-valve tappets than for the inlet-valve tappets, so as to make quite sure that the valves really do close. When grinding in valves it is of course necessary to take care that none of the emery paste enters the cylinder or gets on the valve stem, and the valve, valve port and guides should be thoroughly cleaned before reassembling the parts, oiling the valve stems during the process. After regrinding valves it is usually necessary to readjust the tappet clearances, carefully tightening up the lock-nuts so that they cannot work slack. Each valve should be examined in turn to make certain that it is never held off its seat, nor has too much clearance—the clearance should never be less than $\frac{1}{64}$th of an inch, and never more than about $\frac{1}{32}$nd of an inch—but in order to get the quietest and best running it is advisable to adjust the

tappets while the engine is still hot and the valve stems expanded to their maximum amount. It is not always easy to see if the clearance is right, especially if the head of the valve tappet is much bigger than the end of the valve; the tappet head may be a bit soft, and the end of the valve then punches a slight depression into it, so that the clearance is really more than it appears to be. It is, however, always preferable to have too much rather than too little clearance, as, although the engine will be noisy, there is less fear of burning out the valves.

If for any reason a camshaft has to be removed, careful search should be made for any marked teeth, and care exercised that the teeth of the timing gears are again correctly meshed when putting the camshaft back again. Occasionally, a valve sticks in the guide, due to insufficient lubrication, or it may be that the valve stem has warped. If a spot of oil on the stem is not sufficient to make it operate again the valve should be removed, and the stem rubbed down with a piece of emery cloth, or, if badly warped, carefully straightened in the jaws of a vice, after which it may be necessary to regrind the valve on to its seat. If the engine is provided with screwed valve caps the threads should be smeared with graphite and oil before replacing the caps, otherwise they may seize and be very difficult to remove. A driver should make quite sure that these are screwed up quite tight, and that there is no leakage. A simple test for leakage is to pour a little oil round the joint when the engine has been started, when any leakage will be at once apparent by the oil being blown away from the joint.

Cooling.—In small engines it is possible to rely on air-cooling, as on motor-cycles, but in larger engines a water-jacket is provided, and water circulated through this either by pump or natural circulation. In most cases it is usual to provide a fan to assist the cooling of the water as it passes through the radiator, and the fan belt should be kept at the proper tension, otherwise there will be slip.

Water-cooling troubles make themselves evident by steam being generated, but so long as steam is not blowing away, even if the radiator is uncomfortably hot to the hand, there is no danger, as an engine works best when the water is just below boiling-point. Like most complaints of engines, overheating may be of gradual growth, or it may develop suddenly. In the former case it means that the water-jackets and radiator have become coated with scale such as we find in a domestic kettle, except that the scale may also include rust and grease. Scale interferes with the passage of heat to a very great extent, but much of it may be removed by filling the jackets with a hot strong solution of common soda, then after leaving it to stand all night, drain it off, and thoroughly wash out with clean water. Soda must not be used if the radiator or pipes

are made of aluminium, because soda is injurious to this metal. In such a case it is better to use Boilerine Tablets, or a solution of carbon tetrachloride.

If overheating shows up suddenly on an engine that has previously given no trouble, we must look for a broken or slack fan belt, a faulty pump, or leaking joint allowing water to escape, or the accidental opening of a drain tap. The most serious cause of overheating, however, is a cracked cylinder, as a very minute crack will allow gas to escape from the cylinder into the water-jackets, and the water will quickly boil. Some drivers appear to have difficulty in making tight joints in rubber connexions, but if a little rubber solution is smeared on the pipe it will not only act as a lubricant, but when it sets it will ensure a good joint.

Transmission Gear.—The transmission gear commences with the clutch and finishes at the road wheels. The two main portions of a clutch should disengage positively when the clutch is out, so that there is no dragging on the gearshafts. If the clutch becomes greasy it will slip, causing heating, and probably burning the lining, while if it is allowed to become fierce, it makes starting difficult, and throws undue load on the transmission system. A slipping clutch may be caused by insufficient spring pressure, the lining being badly worn, or worn so as to leave a ridge which prevents the cone entering any further, in which case the ridge can be removed with a chisel, sharp knife, or file. If none of the above causes is present, but the clutch still slips, a new lining should be fitted as soon as possible. Meanwhile, as a temporary expedient, thin strips of metal can be inserted underneath the lining between the rivets. A fierce clutch may be caused by too much spring pressure, or by the rivet heads standing proud of the lining, in which case the clutch will slip a little at first, and then take up suddenly. The remedy is to drive the rivets further in with a punch, so that they are below the surface of the lining. Another and frequent clutch trouble arises from the centre or spigot bearing becoming so worn as to allow the clutch cone to sag, and fall out of truth with the fly-wheel. This makes gear-changing a very difficult matter, because the clutch is never really free. If a clutch slips badly, the first thing to do is to wash the lining with petrol, and if the lining is of leather it should then be reconditioned by dressing it with castor oil or collan oil and leaving it to stand disengaged overnight, so as to allow the oil to soak in. If, however, the lining is of fabric, no oil should be put on it. As a temporary measure for a slipping clutch, it should be dusted over with fuller's earth, or, in the case of a fierce clutch, with powdered graphite, or french chalk.

Multiple-disc clutches are now frequently used, some of them being enclosed in an oil bath, whilst others are of the dry type. In

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the oil-bath type the case should occasionally be drained and washed out with paraffin and new thin mineral oil then put in. If thick oil is used it is liable to become sticky, and may cause slipping, whilst mixtures of engine oil and paraffin should never be used.

Between the clutch and gear-box many vehicles are provided with a small brake or clutch stop, the object of which is to bring the rotating parts of the gear-box to rest when the clutch is out, so as to make gear-changing easy. Attention should be paid to this small brake to see that it is neither too fierce nor too slippery.

The next link in the transmission is the change-speed gear-box. It should be supplied with the right quantity of suitable oil and occasionally drained, washed out with paraffin, and a supply of fresh oil then added. This cleansing and replenishing is necessary because, no matter how carefully used, fine particles of metal dust or chippings become separated from the gears, bearings, change-speed forks, etc., and if allowed to accumulate they cause extensive damage. The ideal lubricant is a good heavy mineral oil, but unfortunately some boxes will not retain it, and in such cases it is a common practice to mix oil and grease together; neither must be of the kind which produces a soapy mixture, because this implies the presence of acid, which will etch highly polished surfaces and cause damage. As a general rule the thinnest mixture of lubricant the box will retain should be used, not only because it flows freely to every part, but because it offers less resistance to the gears.

From the gear-box the drive is transmitted to the driving wheels through chains or a propeller shaft to the rear axle. If chains are used, it is useless to attempt to lubricate by pouring oil on to them. The only effective way is to remove the chains, wash them thoroughly in paraffin, drain them, and then soak them in a bath of hot grease and graphite, and again drain them. Any excess of grease should then be wiped off, or it will collect dust and grit. If chain-cases are provided they should be maintained in an oil-tight condition, and the oil kept up to the proper level. The chains should be kept at a proper tension—a little slack, but not slack enough to flog.

If universal joints are not properly lubricated, wear will take place, and backlash develop and damage all keys and gearing. The back-axle or differential case requires the same attention as is given to the gear-box. If pieces of metal are found on filtering the oil drained from casings, something is wrong, and the matter should be reported at once, or serious damage may follow.

Conclusion.—As a final word let me add that the best possible way of reducing the cost of maintenance of a tractor is by giving close attention to the matters which I have mentioned. If this is done, and the brakes and steering connexions are kept properly adjusted and all nuts and bolts kept tight, there is little to go wrong

in a modern machine, apart from fair wear and tear, calling for the replacement of worn parts by new ones. If the care which I have advocated is not given regularly, abnormal wear and tear will take place, heavy costs for renewals will be incurred, and the value of the machine will rapidly depreciate. I would again urge owners of tractors to treat their machinery as they would treat their animals. If they do so, they will find themselves well repaid.

PRACTICAL EXPERIENCE OF POWER ON THE FARM

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I PROPOSE to deal in this paper with the application of power in my immediate district, and chiefly on my own farm of 330 acres, of which about 225 are under cultivation. The soil is a sandy loam, and with three exceptions the fields are fairly level. The farming in the district is based chiefly on corn, cattle and sheep; there are some farmers who produce milk, and some grow potatoes on part of the root break. My practice has been to depend chiefly on the live-stock department—on sheep, pigs and poultry—and on the arable land; to widen the range of crops by growing a considerable acreage of potatoes, carrots, parsnips, peas and green vegetables, in addition to corn and the usual roots. I have grown sugar-beet during the last three years. My farming, therefore, may be described as semi-intensive—organized, it may be added, as a business proposition.

The following figures, extracted from the annual reports of the Ministry of Agriculture, show a steady decline in the number of horses on farms in England and Wales:

Horse-Power

	Horses, Mares and Colts	*Acres of Arable Land*
1911-1915 . . .	1,165,000	11,131,000
1916-1920 . . .	1,134,000	11,805,000
1921-1925 . . .	1,064,000	11,144,000
1925 . . .	967,000	10,682,000
1926 . . .	927,000	10,548,000
1927 . . .	894,000	10,310,000

The decline in numbers is evidently related to the shrinkage in the area of arable land, but the introduction of the commercial motor for industrial haulage has restricted very considerably the market for horses, resulting in a considerable fall in the number of foals bred on the farm. The Ministry, however, draws attention in the 1927 returns to the fact that the decline in breeding has been nearly stopped. Are we to conclude from this that horse-power in industry and on farms has been brought down under present conditions to the lowest point compatible with efficiency? It may be so; I am afraid, however, that I cannot give a satisfactory answer.

What are the chief reasons for the retention of horses on the farm? The reply is that horses are a handy and really effective source of power. They are the farmer's trusty friends in all weathers, and in all situations—on wet land, on sloping or hilly land, in chain work or shaft work, and are always able to give reliable service. They are slow, but they are very sure.

Cost of Horse per Working Year

	£	s.	d.
Food	25	4	0
Shoes, repairs to harness and sundry expenses	6	5	0
Risk	4	0	0
Depreciation	4	0	0
	£39	9	0

I find, therefore, on my farm, where it is possible to work horses about 260 days in the year, that the cost per day is about 3s.

Cost of Ploughing per Acre

	Acres per Day	s.	d.
Two horses with one-furrow plough	$\frac{3}{4}$	18	0
Two horses with one-furrow plough	1	13	6
Three horses with two-furrow plough	$1\frac{1}{2}$	11	0
Three horses with two-furrow plough	2	8	6

By using a three-horse team and a double-furrow plough the cost of ploughing is brought down very considerably, and the same principle can be applied with economical results to other implements. One of the most recent improvements is the "Gower" two-horse root drill. It is adapted for sowing mangolds, sugar-beet, swedes, and similar seeds, over four rows at one operation, thus covering the ground at twice the speed of the ordinary mangold drill; a further gain being that the ridges are made at the time of sowing.

Each ridge is made by two concave breasts converging from front to back, and the seed is deposited at the required depth immediately in front of the closing ridge. A special feature of the "Gower" drill is its capacity of working when the surface is wet after a shower.

Another valuable implement for ridge work is the pole ridger, carrying three bodies, which reduces the cost of ridging for potatoes by 50 per cent., and earthing-up by 66 per cent.

There is no reason to believe that the efficiency of horse-drawn implements will not be increased still further.

Engine Power on the Farm

Steam Tackle.—Steam ploughing and cultivating in this district are usually done by contract, the price per acre being 16s. to 18s. for ploughing, and 15s. to 16s. for cultivating twice, and 8s. per acre for harrowing twice. The farmer provides the necessary water and about 15 cwt. of coal per day.

The cost per acre is evidently not less than with horses, but there is of course the very decided advantage of rapid execution of the work.

The charge for mole draining is 9d. per chain, measured along the drain.

Tractors.—Tractors are now within the financial capacity of the average man, and it is probable that with the general-purpose tractor we shall see very considerable developments in the near future. At the present time farmers have not quite sufficient confidence in tractors; they know of too many now lying on the scrap-heap, and they know also of heavy bills for repairs, and of much valuable time lost in waiting for renewals of broken parts. Depreciation is a very heavy charge against the tractor. At their best, however, tractors are invaluable in times of pressure because of their speed and of their capacity for working continuously over long periods when it is necessary for arrears of work to be overtaken, or to make the most of periods of favourable weather.

During the last seven years I have used a Wallis tractor, which I have found comparatively easy to handle; it has sufficient speed and power, and is evidently economical of fuel. It is able to travel fairly well on loose ground, and, speaking not as an engineering expert, I have always considered that this power of easy travel is due to its light weight, to the width of its wheels, and its wedge-shaped gripping spuds.

The most suitable kinds of work for a tractor are, in my experience, the hauling of the two-furrow plough, the cultivator, and the self-binder; for belt-work it is excellent. In ploughing there is a certain loss of control over the plough itself—operated as it is from

the front—and this lowers to some extent the efficiency of the work, especially on ground sloping sideways. I have not found harrowing and rolling very suitable work for the tractor because of the wheel-tracks, especially after crops have been sown, as subsequent harrowings fail to touch the young weeds growing along the tracks, and grass and clover seeds falling on these tracks are difficult to cover with sufficient soil. The hauling of the grass-mower has not been quite satisfactory; the wheels of the tractor travel along the edge of the swath, compressing the newly cut grass and rendering the work of the swath-turner more difficult. This defect could be improved by a more careful co-ordination of function between tractor, mower, swath-turner and horse-rake. A further difficulty has been the breaking of the cutting knives and several axles. A point in favour of horses is that they usually pull up when obstructions are met with, and the bill for repairs is correspondingly less than when tractors are used. Perhaps our implement makers will design a more suitable mower?

The hauling of the self-binder is perhaps the most suitable harvesting job for the tractor, as this is killing work for horses on hot days. My binder is a Massey Harris, and cuts a width of six feet. The speed attained is greater than with horses, and the knives cut smoothly in consequence. There have been no breakages due to the tractor which could not equally well be due to horses. There is a loss of cutting width when turning the corners, and it has been necessary for the man in attendance to cut them back with the scythe. There is a device, I believe, which enables the binder to cut the corners more completely, but I have not seen it in use. In difficult cutting, or in a crop of variable length, it is necessary to have a man or a boy on the binder itself; the driver of the tractor, however, being frequently able himself to manage the work of cutting after being well started.

The question of designing wider implements for tractor use in corn and grass harvesting has often been in my mind; but for English conditions and with crops which are often above the average it is difficult to see at the moment how these heavier crops could be handled economically by such implements. It would be a much simpler proposition with lighter crops, and in such cases wider implements could be operated with advantage.

The Tractor of the Future.—The improved tractor must, in my opinion, be of the general-purpose type—of light weight, of simple construction, easy to start, handy in the field and well protected from dust and grit, both inside the engine and about the bearings of the travelling wheels. The tractor must be powerful enough for the work, with low fuel and oil consumption, not too noisy when working, and backed by an efficient repair service.

The driver's comfort must be considered; a suitable platform

and seat must be provided; the driving wheels must also be well guarded to keep the dust away from the driver in dry weather.

This improved tractor must be in the charge of a capable man, sufficiently skilled to keep the tractor running under reasonable conditions. When the tractor is in the shed it will be necessary to provide him with suitable alternative work, which will stand the higher rate of wages that must be paid him.

Cost of Working a Tractor.—The cost of ploughing with the tractor does not appear, in my experience, to be cheaper than with horses when the latter are pulling a two-furrow plough. I have not kept complete costings, but my driver has given me the following figures for fuel and oil consumption for a 21-acre field which, in comparison with the figures for other fields on the farm, seem to be typical: paraffin, 25 gallons; petrol, 5 gallons; lubricating oil, 4½ gallons, and about 1 lb. of grease.

Depreciation works out at about £45 per year, and, allowing 90 working days, the average figure is 10s. per day. As ploughing is heavier work than binding I propose to charge the ploughing at the rate of 12s. 6d. per day, and the lighter work at 7s. 6d. per day.

Repairs have averaged about £18 per year, which equals 4s. per day. I propose to charge 5s. per day against the ploughing.

Summary

	s.	d.
Fuel, oil, etc.	2	3
Depreciation (2½ acres per day) . .	5	0
Repairs	2	0
Wages (piece-work)	3	0
Cost per acre	12	3

If we assume that the charge for repairs is the same per day whether a larger or smaller area is ploughed, we can bring down the cost per acre from 12s. 3d. to 9s. 9d. by increasing the area ploughed from 2½ acres to 4 acres.

Harvesting.—The cost of cutting and tying the same field when in oats worked out at about 6s. per acre when calculated at the rate of 10 acres per day, and about 5s. 2d. per acre when 15 acres are cut per day, which is about the same cost as with horses.

Thrashing.—For belt-work I have found the tractor most satisfactory. As against the steam engine, the tractor depreciates more rapidly, and is not so useful in moving the thrashing-box. The drum appears to be operated as steadily with the tractor as with the steam engine, and in fuel consumption the tractor has a distinct advantage. About 5 gallons of paraffin and ¾ gallon of petrol appear to be sufficient for a day of eight hours, and with steam the

coal consumption is about 15 cwt. per day, and, in addition, water must be constantly supplied. The cost of fuel in the case of the tractor is about 5s. 6d., and, allowing 5s. for the heavier depreciation of the tractor, we have the total of 10s. 6d. against, say, 20s. for coal and 5s. for the work of carrying water, making a comparative figure of 25s. for the steam engine. For thrashing on the farm the tractor is undoubtedly an economical power unit. The sawing of timber for firewood in winter is a side-line of considerable importance.

Motor Cultivation.—I have often wondered why so little progress has been made with motor ploughs and cultivators, as it seems that control from the rear has distinct advantages. As a grower of roots on ridges of various sizes I have often seen the young growing plants damaged by the treading of horses. If one had a very light motor-cultivator which could travel between the rows, and operate tines, blades, discs, or other attachments, a great deal of damage could be avoided. Plants in the field may, of course, be destroyed in other ways than by horses, but it is important to realize that, in the case of sugar-beet, with roots having an average weight of 1 lb. (not very large roots), growing uniformly in rows of 18 in. and singled at 9 in. apart, the crop would weigh 17 tons per acre, which is about double the average yield, and indicates that considerable loss occurs in most cases.

Haulage of Farm Produce

I claim to be a lover of horses, but after being thrown headlong into the road on more than one occasion I was driven to the conclusion that it was safer to drive a motor-car than a horse along the surface of a modern road and I made the change-over, though with some reluctance at the time.

Now, I have also taken the farm horses off the road, and the haulage to station and market is done by hired motors.

My nearest station is four and a half miles away, and a local lorry owner has undertaken to haul manures, feeding-stuffs, and various kinds of produce in bags, at the rate of 4s. per ton, but it appears that a powerful competitor will shortly offer to do the same work at a lower rate. The usual load at the 4s.-per-ton rate is from 25 to 30 cwt., but occasionally 2 tons.

By using horses and moving a crop of potatoes at the rate of 7½ tons in two days with one team, I estimate that the cost per ton would be about 3s. 9d. per ton—slightly lower than with the motor. Owing, however, to the greater speed and convenience of the motor, I prefer to keep the horses working on the land.

Sugar-beet is collected from the farm by the railway company's own lorries, unloaded at the station into railway trucks, and sent

by rail to the factory at Kidderminster, at a cost of 3s. 10d. per ton for collection to the station, and 3s. 6d. per ton for railway freight, which makes 7s. 4d. per ton from farm to factory. For road haulage a contract price with a private firm was 7s. 6d. per ton from farm to factory. I have reason to believe that both these contract rates will be lower during the coming season. The beets have, of course, to be carted from the fields to a loading deck adjacent to the hard road, and assistance is given when loading the lorry at the deck.

Summarized haulage costs to Station—4½ miles distant

Horses (2½ ton loads)	3s. 9d. per ton
Light motor-lorry (1¼-1½ ton loads)	4s. per ton
Heavy motor-lorry (6 ton loads)	3s. 10d. per ton

My chief market town is Wolverhampton, which is fourteen and a half miles away. The following figures represent the charges from the farm to the market and to various depôts in the town:

Potatoes in bags (2 ton loads)	8s. per ton
Potatoes in hampers (2 ton loads)	10s. per ton
Carrots, parsnips, peas and cabbages (1¼ ton loads)	10s. per ton
Sheep and pigs (about 15 sheep)	15s. per load

An economy of some importance resides in the fact that these light lorries can take their loads of from 25 to 30 cwt. direct from the field, except when the ground is soft immediately after rain, when it is necessary to bring out the horse, and cart the load to firmer ground. Heavy motors must always remain on the hard road when being loaded.

The cost per ton when produce is sent to Wolverhampton by road to the station, and thence by rail, is about 15s., delivered to the market, which is, of course, quite an impossible figure.

Summing up, it will be seen that it is still difficult to reduce the cost of many kinds of field work to a point lower than is possible with horse-power, yet I am convinced that a general-purpose tractor, used in conjunction with horses, is a combination which under present conditions gives that variety of power which makes for high efficiency on our medium and large-sized arable farms. There are times when the value of the work done, say, during a spell of favourable weather, makes the actual cost of the job seem extraordinarily well worth while, and these are the times when the tractors give their best service, which may in some cases mean the difference between success and comparative failure.

For road haulage, horses are too slow, and are rapidly being

superseded by motors. I feel, however, that it is better for most farmers to hire rather than to purchase a motor, as, in these days of telephones, there is no difficulty in bringing a motor to the farm almost at any time, which is a wonderful convenience.

In conclusion, it is obvious that mechanical power applied to agriculture is an important factor making for the improvement of farming conditions—a factor which may prove to have a very special appeal to the oncoming generation—and if in this way we can raise the standard of life on the countryside it will be due very largely to the skill and resource of our agricultural engineers. I hope that their efforts on behalf of agriculture may still further result in "better farming, better business, and better living."

ROTARY TILLAGE

By R. D. MOZER

Simar Rototillers

THE subject of "Rotary Tillage" is not a simple one and is not easily condensed, and I must confine myself to stating a few facts and deductions which may prove to be the basis for subsequent developments of this intricate matter. In certain phases of farm management the question is relatively simple—harvesters, automatic milking machines, and many other power-driven implements are manufactured along more or less standard lines, and often there remains only the problem to choose such machines as will give long life and continuous service.

In the department of tillage operations, however, the problem is more difficult. As a general rule, the farmer knows instinctively that such-and-such processes will yield certain results, but there is a wide gap between the process and the final result, and he is accordingly loth to change anything from his former methods, because he cannot foresee step by step what effect will follow the introduction of new methods at any stage of his operations. Hence the difficulties facing the agricultural engineer are very acute.

The first problem to be faced in connexion with the application of power to tillage operations is the nature of the power which should be used, but that is a problem which is beyond the scope of this paper. The second problem is whether the mechanical unit should be designed so as to make use of conventional tillage implements, or whether the implements themselves should be re-designed to fit in, as it were, with the usual consequences of the generation of power by mechanical means. Within the latter category we find

only one class of implement, known in general terms as "Rotary Tillers."

There are, of course, considerable variations between the different rotary tillers, and in general there is a broad distinction to be drawn between those with rigid tools and those with elastic tools. All rotary tillers have for their object the production of a seed-bed in a single operation, and a machine capable of giving such a result without counteracting disadvantages must find its place wherever soil is to be tilled.

Mechanical power being essentially rotary in character, it is only logical to assume that such power should be employed in its original rotary form in connexion with the work of tillage. A simple illustration will suffice. In general, the axis of the rotary tilling unit is parallel to the main axle of the propelling wheels; it corresponds to the back axle of a car, and has a rolling action with the qualification that a certain breaking effect is caused by soil resistance and other factors. Most of us, however, as novices in the art of car driving, have forgotten to release at some time our hand brake and have only experienced a reduction of the maximum output of the engine, and by no means a complete extinction of power.

What probably constitutes the first recorded vision of rotary tillage as an accomplished art is to be found in the pages of Hoskyn's book *Talpa; or, The Chronicles of a Clay Farm*, written when steam-power was being adopted very largely in industry generally. Hoskyn foresaw an implement which, to use his own words, would be one "which completed the whole work of tillage as it moves along" and, "in one comprehensive act—and word—cultivation." Since the time of Hoskyn much has been said and done in the field of rotary tillage, yet it cannot be said that the results achieved, so far as a general adoption of a machine of Hoskyn's conception is concerned, are in accordance with the simple logic underlying the author's words. We need to examine in some detail the reasons why rotary tillage has not been adopted more widely than is actually the case, and it is unbelievable that this method will not be given at least the extensive trial which it deserves, so that the claims of its sponsors should at least be proved or disproved.

The introduction of mechanical power to the farm was in the form of tractors, and rotary tillers only made their appearance in this country after the War. Since the introduction of the latter machines a strong controversy has been carried on as to the respective merits of the two power units as compared one with the other, while each in turn is the subject of comparison with the horse.

Rotary tillers are generally specially designed, self-contained machines, and while modifications in design are usually possible to permit of the use of the power for such purposes as belt-work, etc., they do not at present replace horse-power to the same extent as do

tractors. Nevertheless, it should not be impossible to effect modifications of design to rotary tillers to widen the field of usefulness of such machines to cover most farm operations.

It may be said that all the considerations which are leading to the replacement of horse-power by mechanical power in industry generally, apply, with a few modifications, to agriculture. The horse is an imperfect power generator because it consumes independently of the power supplied and whether required to generate power or not. Again, the horse consumes part of the products of the soil, and is in consequence an adverse economic unit, especially in the case of relatively small farms.

The tractor is uneconomical because, in order to get the necessary adherence, it must be given weight on the driving wheels or track. To drag a plough consuming effectively 4 h.p., a tractor weighing about 18 cwt. is wanted, which practice has shown to require an engine of at least 14 h.p., so that there is a waste of some 70 per cent. of the power generated.

This weight-cum-adherence problem is largely centred in the fact that the plough as used with the tractor exerts a backward draught. Similar considerations need not apply to rotary tillers, where the action of the revolving tines helps the whole machine forward. There is, consequently, a very much lower loss of power between the point of its generation and that of its application.

Nevertheless, rotary tillers so far produced—except the smaller types up to about 10 h.p.—have been wrongly evolved in not taking advantage of all the weight reduction which is possible. It must be admitted with some reluctance that there is at present no rotary tiller which is really fit for the farmer, and that only those more suitable for the nurserymen, etc., are at present sound commercial propositions.

The problem from the agricultural standpoint is a question of the respective merits of the plough and the implements which normally follow it, on the one hand, and the rotary tiller on the other hand. Here we are concerned only to find the best means to produce a tilth or seed-bed. On a properly managed farm the cost of seed-bed making represents about 10 per cent. of the crop value, and a 10 per cent. increase in yield as the result of better or more timely work would therefore cover this part of production costs.

Rotary tillage can effect much greater saving than this, as, for example, by eliminating several operations, by better utilization of manures—which are more uniformly distributed—and by a reduction in the amount of manure required.

The specific weight per horse-power of rotary tillers can be reduced to a minimum, and this reduction means that there is less compression of the soil. A distinction can also be made between the low compression of the soil and the low-friction effect of a set

of independently mounted tines, and the comparatively high friction between the plough and the solid earth which it is required to turn over in large masses.

The fact that the work of tillage is completed in one operation with the rotary tiller is an unquestionable advantage in spring cultivation, and, as seeding is the only operation subsequent to tilling, compression of the tilled soil is still further reduced. Again, the action of the rotary tiller is such that instead of the hard, smooth pan which is left by the plough, the bottom of the tilth is left rough, obviating the necessity to subsoil and permitting percolation of water during rainy periods, to be stored as a reserve for the top soil. Next, it is claimed that the tilth produced with the rotary tillers is a much more uniform and a finer one than can be secured by any other means, with the possible exception of very careful hand labour. The fine even texture of this tilth is productive of better aeration, while it is of considerable assistance in promoting free and rapid root growth.

The principal criticism against rotary tillage is its unsuitability for autumn cultivation. It is thought that because the tilth produced is such a fine one there will be a tendency, with heavy winter rains, for the soil to pan down and set hard. This is a point on which there is much conflicting evidence that must be carefully sifted before any general verdict can be passed. In any case it should be possible to modify the design of the tiller to enable a much coarser tilth to be obtained at will.

The question will be asked as to what evidence there is in practice that the claims for rotary tillage are justified. In the commercial field, rotary tillers are now comparatively well known amongst fruit-growers, market-gardeners and nurserymen, and have justified themselves to a much greater extent in connexion with intensive farming than with farming in its more general aspect. This is not surprising, since the principal objection to rotary tillage—namely, its probable unsuitability to autumn tillage—does not apply in this particular sphere. On the other hand, all the admitted advantages of rototillage apply. Market-gardeners require a fine seed-bed, ability to catch the weather, and facilities for sowing a fresh crop immediately the preceding one has been harvested.

As applied to the raising of root crops, very favourable reports are available, and one case is recorded of rotary-tilled soil yielding a potato crop of 30 tons to the acre. Very favourable results have also been secured with swedes, turnips, mangolds and sugar-beet. On the other hand, a conflicting experience was obtained at this Institute, where swedes were grown in three plots which had been respectively horse-ploughed, tractor-ploughed and rotary-tilled. The latter plot at first gave every promise of being the best crop of the three. Suddenly there occurred a marked change. The soil

became "panned" or hard, the appearance of the foliage fell away considerably, and, in the final result, the crop was inferior in weight to that of the other two plots. My company has been invited to participate in further experiments at this Institute to ascertain whether this apparently deleterious effect of rotary-tilling can be overcome by the simple expedient of inter-cultivation at defined stages during growth. If, with one additional passage with the rotary tiller, with its tines set shallow to skim the surface, the pan can be quickly and effectively disturbed, there will be an answer to the somewhat widespread belief that the rotary tiller is unsuitable as an autumn cultivator.

Leaving once again this rather controversial field we can give a few moments' consideration to other points where the rotary tiller is of undoubted benefit. By a simple depth-regulation arrangement it is possible to use these machines, not only in the preparation of the soil for seeding, but for cultivation at all stages of growth. In the summer months they can be used to promote a fine surface mulch which is of such great benefit in helping to tide over the effects of scarcity of rainfall. They will deal efficiently with weed growths of variable natures, though it is to be noted that repeated cultivation is the *modus operandi* for destroying these pests effectively, for, unless frequent cultivation is resorted to, a marked increase in weed growths is noted, which is incidentally a finger-post pointing to the possibilities of rotary tillage as a fertilizing method.

Reviewing the field covered by this new method it may be stated that rotary tillage is an accomplished fact in certain departments. It exists as a fully evolved commercial force in such work as nurseries and for specialized crops, and it is extremely useful in its present form for certain farming operations requiring intensification of methods. The larger types of existing rotary tillers represent by no means the last word, and we may say that, so far as general farming is concerned, rotary tillage is still in its infancy. It is doubtful if there is one agriculturist who is not sufficiently far-seeing to watch with interest the developments in the practice which are bound to take place during the next few years, and, to quote Hoskyn once more: "In the Arts as well as in morals, difficulties are opportunities."

ELECTRIC PLOUGHING AND TRANSPORT

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Part I.—*Electric Ploughing*

Ploughing is one of the most important and heaviest of farm tasks and also the most expensive item on the arable farmer's bill. Opposition to mechanical power for ploughing is often met with in agricultural circles. It is claimed that the introduction of power-driven cultivating machinery, instead of reducing costs, would of necessity increase them, as the keep of the horses would be the same and the mechanical power would only be carrying out the work that the horses would otherwise be doing. There is, however, one fallacy in this argument, for the work of ploughing cannot be extended over a long period and horses can be used for this purpose only during slack periods. For land to be well cultivated the ploughing must be completed as early as possible in the autumn; and again, it often occurs in this country that long wet periods are experienced which delay work on the land, but, when a favourable opportunity presents itself, the farmer who has something quicker than the horse to carry out the work is in a very advantageous position. Further, the modern electric plough can now be adapted for all forms of field work—such as harrowing, rolling, harvesting, etc.

Another argument commonly used is that English fields are too small for this kind of work. This argument, however, is made on the assumption that all electric ploughs are very large sets, capable of covering an enormous area in one day. There are, however, the round-about and tractor types of ploughs, which are quite suitable for small fields—there are many in use to-day in vineyards in the South of France; these vineyards, it must be admitted, are a more difficult proposition than the smallest of fields. A great deal of the author's work has been in the direction of solving the problem of the ideal type of ploughing equipment for the small farmer of individualistic ideas.

It is doubtful whether the operation of ploughing, as at present practised, is really an essential part of tillage, and in this respect it is interesting to note the rapid progress made by the rotary cultivator during the past few years; these machines lend themselves extremely well to an electric drive. The flexible cable passes from

a small mast on the machine through a pulley at the top of a pole fixed at the side of a field, it then hangs in a loop, the end of the loop passing to the mains being fixed to the top of the pole. In the loop there is a pulley carrying a weight, so that the cable is automatically paid out or drawn back at a constant tension, thus preventing it from being accidentally run over.

The 10 h.p. size can deal with an area of from 0·2 to 0·5 of an acre per hour, at a depth of from 4 to 10 in., travelling at a normal speed of 1½ miles per hour.

The 30 h.p. size can deal with an area of 0·5 to 1·5 acres per hour, working to a depth of 14 in.

There are a number of different systems of electric ploughing in operation to-day, though they practically all fall into one of two classes—viz. tractors or rope haulages. The capacity of the larger ploughs is enormous, many ploughing up to 30 acres in one day.

These sets are equipped with either 80, 100, 125 or 150 h.p., 5000 volt, three-phase, slip-ring induction motors, many of which are capable of a momentary overload of 60 per cent. The general design is based on British steam-plough experience, hence only the electrical features are really new. The main disadvantage of this equipment is the very great weight of the haulage sets, which is sometimes as much as 14 tons for each winder, thus large headlands are required. Many ploughs of this type are to be seen in France and Germany, and also in Russia. The method of operation is essentially the same as with the familiar steam-ploughing tackle. Two portable electric-motor haulages are placed, one at each side of the field, each haulage having a steel-rope drum, driven by counter-shafting through the electric motor. The average speed of the steel cable is about 1·66 yards per second, though it is possible to reduce the speed to 1·1 yards per second. With this equipment it is claimed it is possible to plough 30 acres per day, with a furrow depth of 9½ to 12 in. The power consumption per acre on heavy clay soil of average moisture content is about 15 units (kw.h.), while the speed of ploughing is 3⅓ miles per hour.

The majority of double-rope system haulages are similar in design, though many are equipped with auxiliary petrol engines of about 50 h.p. to enable the haulage to move from field to field and from farm to farm, while in others the familiar anchor-wagon device is used.

Continental manufacturers have realized that more attention must be paid to the need of the individual farmer, and have designed sets with this purpose in view.

The Estrade equipment has a number of novel features. The haulage cable passes through a pulley at the end of a pivot arm, whose movement is assisted by a series of oil dashpots. The resultant of the pull and the weight of the haulage always passes

through the line joining the points of contact of the soil and the two inside wheels. These wheels are fitted with flanges, which, with the rims, enclose a prism of earth. In this way great stability is obtained, for, instead of depending on the friction of the iron arms on the earth surface, the much greater friction of this compressed prism of earth on that lying beneath is utilized. The manufacturers claim that this type of haulage gear can provide a pull of three times the weight of the set.

In another new machine, ramps, or inclined runners, are provided upon each haulage set, and when the plough reaches the end of its journey it mounts up on the haulage set, ready for transfer into position for the next set of furrows. Thus, headlands are reduced to a minimum and manœuvring is greatly facilitated.

Electric Tractor Ploughs.—One of the main problems is the method of dealing with the flexible cable connecting the tractor to the supply point. The best principle evolved so far is to mount the feed cable-reel on the tractor itself. In this way the cable is paid out and laid to rest on the soil instead of being dragged after the tractor, while on the return journey it is picked up and wound on to the drum. Various devices are used to ensure that the cable-reel winds and unwinds at the correct speed.

In Italy the ingenious method of attaching the cable to a small balloon (lifting power about 100 lb.), and thus raising it out of the way, has been employed.

Electric tractors fitted with a tramcar-type collecting trolley or bowl, picking up the current from a bare overhead conductor, have not proved satisfactory on account of the trouble in designing supports so as to maintain sufficient tension on the conductor and at the same time facilitate progressive movement at the end of each furrow.

Tractor ploughs are generally fitted with electric motors of from 20 to 30 h.p., and when equipped with three-share ploughs will plough, on an average, 6 acres per day to a depth of 8 in., the current consumption being about 28 units (kw.h.) per acre.

On the author's farm a 12 h.p. modified roundabout electric plough is employed.

The author considers that the double-winder rope system, with petrol engine for field transport, is the most satisfactory for large contractors working over large areas. The *ideal* plough for the farm of 200 acres and upwards has yet to make its appearance. The author suggests that it should be designed with a half-creeper track. The flexible cable should be raised above the ground, with automatic winding and an automatic-feeder cable, similar in design to that employed on the M'Dowall plough. A storage battery should be provided for moving the equipment from field to field, and when not in use on the land or within reach of overhead lines.

The main motor should be of about 25 h.p., while an additional winding motor of about 2 h.p., with an automatic hysteresis control, should be incorporated for operating the cable-drum. A mast should be fitted on the tractor to support the cable so that it hangs free in the air for a distance of about 30 to 40 yards. A plough should be mounted at both ends of the tractor so as to obviate the necessity of turning at the end of each set of furrows. A tractor of this type would plough from 40 to 60 acres from a single contact in the middle of the field. This tractor could also be used for such work as cultivating, harrowing, harvesting, rolling, seed-drilling, etc.

While it is not possible to give exact figures as to the cost of electric-ploughing, since so much depends upon special circumstances in each area, yet the author has calculated the cost of operating some of the machines from figures given by manufacturers and users. On the double-rope system with two haulages, the cost works out at 5s. 7½d. per acre, while the figure for electric tractors is 5s. 1d. per acre. These figures do not, of course, include overhead expenses, but include depreciation, interest, cost of cable, repairs, labour, and electric power at 1d. per unit, the depth of ploughing being from 6 to 8 in. When allowance is made for overhead charges these figures still compare favourably with the contract prices quoted for all other forms of ploughing. Another way of dealing with the cost is to mention that the consumption of electric current for ploughing varies from 15 to 22 units (kw.h.) per acre—a comparatively small sum at 1d. per unit, the usual charge.

There is, of course, still room for improvement in the design of electric ploughs, but it is rather refinement and evolution that is needed, coupled, of course, with the provision of an adequate distribution system to supply the large amount of electric power required.

For the supply of electricity to rural areas the usual type of overhead, three-phase transmission line will no doubt be used, and the only special feature introduced for field work is the method of connecting the high-tension lines to the portable transformer wagon. For temporary tappings it is often done by means of special hooks, having insulated handles and cable connected to the transformer cabin, though a better way is by means of permanent "fool-proof" pole contacts, of which special types already exist for pressures up to 10,000 volts. These are very easily operated from the ground by a long rod, and remove any possibility of wear and damage to the main transmission line.

PART II.—*Electric Transport*

An ample supply of power, which will be necessary for ploughing, will bring in its train many other electro-mechanical aids to the

farmer, and chief among these will be comparatively simple transport equipment which will both expedite and facilitate the work on the farm, thereby reducing the amount of labour employed per unit of work performed.

Handling Crops.—A large proportion of the cost of hay and corn is accounted for by the high labour costs involved in handling the material both in the field and the buildings. A useful method of unloading the crops at the barns is to utilize specially prepared slings or automatic grab forks, in conjunction with an obvious system of ropes or nets, placed in the wagon before loading. The whole operation of unloading can then be performed by one man.

The method most frequently employed on farms on the Continent for hoisting these loads is a modified form of the Temperley transporter system, operated by an electrically driven hoisting gear provided with two hoisting drums and sets of brakes. The gear is conveniently located near the unloading point, thus giving complete control to the men in charge. When the load is hoisted to the top of the barn the pulleys jam, and the load can be traversed in either direction. The whole arrangement is of a very cheap and simple design, and can be operated by a 3-5 h.p. motor.

Transport equipment can also be used profitably at thrashing time—for instance, electrically driven chain-conveyers should be employed to transport the sheaves from the rick or barns to the thrashing-machine, with an automatic device incorporated on the thrashing-machine for cutting the bands on the sheaves and separating each sheaf before delivering it on to the drum. The thrashing-machine could then be permanently mounted on foundations about 4 ft. above floor-level. The installation of a permanent thrashing-machine would make it possible to deal with straw in the following ways: the straw could be (1) baled on leaving the thrasher, (2) passed through a sheaf binder, (3) blown to a straw-yard through a tube, or (4) transported by an inclined elevator. With methods 1, 2 and 4 the straw should be delivered on to a horizontal conveyor, so that at convenient intervals trap-doors can be placed in the run-way, which permit of the delivery of the straw at any desired point. When method 3 is adopted the delivery tube can be as long as 200 yards. It is usual to make up the length with 10 ft. lengths of light galvanized piping. At the end of the last tube an arrestor is fitted so as to collect the straw neatly at the desired point. For driving the grain a distance of 50 yards a 5 h.p. motor-driven fan is required, while an 8 h.p. motor-driven fan will double the distance, and a 10 h.p. size will carry it 200 yards. Where fans of efficient design are used, and attention is paid to the form of ejecting device, even smaller motors can be employed. The capital cost of these conveyors is not high, as they are of very simple design.

The grain can be moved by either "Jacob's ladders" or special

worm-conveyers, delivering it on a horizontal or inclined belt-type conveyor direct to the granary.

With mechanical assistance of this nature one or two men only are needed at the thrasher, while other two pitch the sheaves on to the conveyor.

Central Manuring Plants.—A system of manuring market-gardens by means of stand pipes in the orchards has been carried out for quite a number of years on many Continental farms, especially those in Switzerland. The stand pipes are connected to a manure tank adjoining the main cow byres by means of underground pipes. The urine from the cowsheds flows directly into the tank, and when the plant is about to be used, old rotted manure is thrown into the tank and water added, and the whole contents agitated by means of revolving arms or by circulation through centrifugal pumps.

The question of the supply of electric current for transport purposes and for electro-mechanical appliances for work in the field and in the farm-buildings is relatively simple, if farming is carried on on modern lines, since the power demand would be so great that electricity-supply undertakings would be anxious to cultivate the rural load and would therefore be only too pleased to provide the necessary distribution system.

Recently the writer, in conjunction with Dr A. Ekstroem (the well-known Swedish authority on rural electrification), has prepared a scheme for completely electrifying the whole of Lincolnshire—which is typically an agricultural county. If the scheme can be carried through, rates as low as ½d. per unit will be offered for purposes where the current is used for long periods—such as thermal storage, electric cookers and water heaters. It is hoped to bring a supply of electricity to over 75 per cent. of the inhabitants of the county within six years. In each of the above-mentioned areas a number of typical farms will be completely electrified (including electric ploughs) in the reasonable manner that the farmers would do themselves if they had had many years of experience of the use of electricity, and also knew what farmers in other countries were doing.

THE DISCUSSION

Sir Merrick Burrell, in opening the proceedings, said that the purpose of these meetings was to bring together farmers, representatives of industries connected with agriculture, and agricultural scientists for the discussion of specific problems in agriculture. The present Conference was the sixth of the series, which had already dealt with lucerne, fodder crops, sugar-beet, green manuring, and the art of cultivation.

The subject chosen—"Power for Cultivation and Haulage on the Farm"—was beyond question of wide importance at the present time: how far could mechanical power aid the farmer, what form of power was best, and to what extent would it aid, or replace, traditional horse-power operations? His personal opinion was that the horse would continue to hold its own, although mechanical power would prove a very useful aid. He thought that the bulk of the discussion would centre around the tractor, but he asked the audience not to forget the long and honourable record of steam-power, and the claims of electric-power, in which large developments might come in the near future.

Mr W. C. Dampier-Whetham, in opening the discussion, said that his own experience was mainly on grass-land farms. Horses were cheap to buy, depreciation was small, a team could be split and distributed to different pieces of work—and they were better for small fields. The small development in power in agriculture as compared with other industries is due to the following reasons: (1) industries were localized in factories, whereas agriculture had a diffuse and spasmodic requirement; (2) the farmer's main source of power was the sun, whose energy was utilized by the growing crops, and all other forms of power were subsidiary to this. The development of electric-power was held up in England by the high cost of overhead lines, due to stringent safety requirements. They cost £500 per mile against £200 on the Continent. The amount of power needed per acre was small, but over the whole rural area the load would be economic.

Mr H. Deck (Ransome, Sims & Jefferies) considered that the use of electricity for barn machinery was its most likely outlet. For cultivation and haulage work permanent and movable cables and heavy batteries would be highly inconvenient He thought there would be little immediate change, except in the direction of more economical design, either in the tractor or the implements designed for use with it. Nevertheless there were great possibilities

in deeper ploughing and cultivating. He stressed the importance of speed in all farming operations in our uncertain climate.

Mr Bosanquet of Alnwick (delegate of the Northumberland N.F.U. to the Conference) said that as a practical farmer he supported all that Mr Porter had said. He farmed 1800 acres of light hilly land, mostly reclaimed from moorland within the last one hundred and fifty years. At first tractors were unsatisfactory because buried boulders broke the tackle, but they were excellent for thrashing. He used motors exclusively for haulage, except for carrying rations to the farm-buildings and transporting women workers between the fields and their homes each day, for which light horsed carts were used. This practice has been found so advantageous to the farm work, and is so much appreciated by the workers, that the horse will shortly be replaced by a light motor-lorry, which would also be used for ordinary transport.

Mr J. R. Bond (County Organizer for Derby) thought that the imported-meat trade was largely responsible for the present depression in agriculture, and believed that laying down land to grass could not help. The present difficulties largely arose because of our traditional practice of keeping animals partly to supply manure.

Steam cultivation was too costly. There had been little improvement in engine design since 1850. The engine need not be heavy, and in any case the distribution of weight over the present form did not correspond with the point at which the pull was experienced. Very little had been said about the destruction and killing of weeds during cultivation operations. It seemed as if half of a farmer's life was spent in getting a tilth, whereas it was his experience that more than half of a farmer's life was spent in destroying weeds. He thought that if an efficient machine for this purpose could be devised the time of cultivation work could be greatly reduced.

Mr Black (President, Suffolk N.F.U.) stated that his experience was gained on heavy land in Suffolk, where he could not work his horses for 260 days a year as Mr Porter did. He found the tractor essential to get through the necessary work in time. On large farms it was better to have both heavy and light tractors and lorries rather than general-purpose types. He supported conveyor distribution for produce in the granary.

Mr Van Dijk (Messrs MacLaren's engineer for export trade) said he had come over from the Continent especially for this Conference. On sugar and tobacco soils in Sumatra, where the

soil resistance was very high, he had, after ten years' work, reduced the plough draught by 50 per cent. Had he had the advantage of the Rothamsted studies on soil resistance he could have solved the problem much earlier. The vital question to-day was to reduce tractor costs. This implied a reduction in the number of moving parts in the engine, and the use of crude oil—the Diesel engine was the solution. It was now in use successfully for cable tackle, and smaller tractor types were also in use.

Mr Hugh Young dealt with his experience as a farmer on hilly land at High Wycombe. He stressed the necessity in tractor design for keeping the weight as near the ground as possible and well distributed over a large base. The front wheels of one of his tractors tended to be pulled off the ground when travelling uphill, while another, when working across the hill, tended to topple over sideways.

The purchase between the tractor wheel and the land was the weakest point in present-day design; a four-wheel drive or track-laying type would be better: his three-wheel drive tractor hauled a binder last summer on land so greasy that the two-wheel drive tractor could not manœuvre itself with no load at all behind it.

He strongly urged the desirability of an efficient two-furrow one-way plough for the tractor: no horse plough was needed to open and close the furrows between the lands; no time was spent in driving along the headland between lands, which, for an acre with 200-yard furrows, meant some 380 yards extra travel; the passages over the same piece of headland were three against eighteen with the fixed plough. He invariably used one-way ploughs with horses, and was surprised at the little use made of them in England (except in the anti-balance form in the south-west counties), in view of their great popularity on the Continent. Finally, in his hilly land the tractor was worth its cost for binder work alone.

Major C. E. Bentall (Heybridge Works, Maldon) raised the question of the performance of implements rigidly attached to the tractor. If the essential feature of such an implement was that the wheel of the tractor took the place of the land wheel, it would result in uneven work on uneven land. This seemed an argument against a simple rigid attachment between tractor and implement. With the existing types, the hitch was flexible, thus allowing the plough to follow the contour of the land and maintain an even depth of furrow.

He drew attention to the value of the tractor for broadsharing. This implement was formerly very popular, and did undeniably

valuable work, particularly in stubble cleaning, but its use had been largely discontinued, mainly for the reason that it was considered to overtax horses.

Mr F. H. Johnson (Bull Motors, Ipswich) considered that electric power would be economically used for cultivation only if a single engine were used, the implement being pulled backwards and forwards between this and an adjustable anchor truck, by means of a double haulage rope. This method would halve the number of permanent supply cables needed on the farm and would eliminate the necessity for any flexible conductor winding and unwinding with the movement of the implement—an arrangement that is cumbrous at the best.

Although the above scheme is the most practicable so far as distribution is concerned—which is the governing factor—there is the great disadvantage that the electric tractor and anchor truck must of necessity be hauled to their work by internal-combustion or steam tractors, and the only way that this can be eliminated is to fit the electric tractor itself with an engine, or heavy and expensive batteries, which will enable it to travel by road when disconnected from the distributing wires. The latter introduces complications which would be highly unsatisfactory in the hands of ordinary agricultural labour, and would certainly be very difficult and expensive to install and operate where the supply is alternating current, as it would be in almost every case of rural electrification. For the larger ploughing equipments the question of petrol-electric operation is well worth consideration, as by this method the control of the tackle could be simplified enormously. The whole equipment could be handled by means of a simple drum-type controller, similar to that used on tramcars. The capital cost of the tackle compared with steam gear would be reduced, and the depreciation would also be less. There would be a considerable saving in labour, since no supplies of boiler-feed water and coal would be needed. The petrol-electric system could be made perfectly reliable; the reliability of the electrical portions is at least equal to that of the petrol engine, and, with properly designed machinery, the depreciation on the electrical portion is almost negligible. One advantage of the petrol-electric system is that it would give a very wide range of hauling speeds. It could very easily be so arranged that the maximum tractive effort for which the equipment is designed was developed at any speed from standstill to the normal full speed, corresponding to the maximum output of the engine driving the dynamo. The same plant could also be made capable of developing half the maximum tractive effort for which it was designed, at a speed as high as twice the normal hauling speed if necessary. This would enable a great variety of work to be handled, and on the

lighter work would enable a great economy in time to be effected, provided the maximum speed available could be utilized effectively.

Therefore, by utilizing the electrical drive, an equipment could be provided which has a very wide range of hauling powers and speeds, and able to utilize the various implements which it is designed to haul, to their full capacity. Provided the electrical engineer is shown what is required, there is no reason why he should not produce plant which will deal in a highly efficient manner with a large variety of haulage and other problems.

Lieut.-Col. F. GARRETT, C.B.E. (Leiston Works): To get more men on the land and to pay the higher wages necessary we must introduce, as far as climatic conditions allow, mechanical means into agriculture, and thus increase the output per man. My firm has recently developed a device for reducing the labour of haulage on soft or wet land. The idea applies to all vehicles (even tractors) and enables, for instance, one horse to haul a load off heavy land that formerly taxed two.

I disagree entirely with Mr Bond on the development of steam-power; it has advanced quite as much, by higher pressures, super-heaters, valve-gears and turbine systems, as any other form of power. In haulage, ten-, six- and four-ton load steam vehicles are popular, and beat the internal-combustion engine in cost of running, durability and capacity for overloading and overspeeding; steam-power has still many useful outlets in agriculture.

The two grave obstacles confronting electric-power in agriculture are the absence of cheap and light batteries, and the high capital cost of current distribution systems.

Mr B. G. SHORTEN (J. & F. Howard, Ltd., Bedford): Steam cultivation on large estates has been successfully proved for many years. The smaller landowners and tenant farmers in many cases employ the service of a contractor owning steam tackle. In this way extensive areas have been kept under cultivation which otherwise would have been found most difficult to deal with.

As agricultural engineers, we deplore the present tendency of so much land being laid down in grass. The time is not far distant when landowners and farmers will find it to their advantage to devote more attention to this question of tillage. The figures plainly show that the importation of foreign meat will increase rather than decrease, and with this undoubted position in view, how can farmers hope to make grass-land pay by producing beef in competition with such an array of foreign competitors?

I do not agree with the suggestion that manufacturers have adhered to the principles of the horse-drawn implements in designing tractor implements. I can assure you this is not so. Most efficient

self-lifting arrangements are now fitted, operated by the driver. It has been suggested that more efficiency could be secured by combining the tractor and, say, two-furrow plough, in one unit, braced together with certain flexible movement. On closer experience problems will be found presenting difficulties—*e.g.* a double-furrow plough closely connected to tractor, negotiating uneven surfaces, is deprived of the necessary vertical and horizontal movements required for dealing with rough and heavy soils, and so far more satisfactory results are produced by independent couplings.

While we believe the demand for tractors is steadily growing, and their usefulness more recognized, it must not be taken as indicating that horse-power is on the verge of collapse. The implement production of my firm is about 85 per cent. horse-drawn as against 15 per cent. tractor-drawn. I believe horse-power will continue to be largely used, more especially by the medium and smaller farmers, and, by reason of the variety of duties performed by them, they will remain first favourites with the majority of farmers. I believe the horse, the tractor and the steam tackle, with their suitable implements, hold an important place in the development of our farming industry, and where well and wisely employed, even under existing conditions, all three can be used with progressive and profitable results.

Mr Harold Drewitt gave some figures for the cost of tractor work on his farm near Chichester. His tractor was bought shortly after the War and was very extravagant in paraffin and oil. His second purchase was made about five and a half years ago, and this tractor, in its working life of three years, ploughed 1615 acres (taking 5 acres of cultivating as equivalent to 1 acre of ploughing); the average cost of operations per acre was:

	s.	d.
Labour, fuel and oil	9	6
Repairs	4	2
Depreciation	4	9
Total	18	5

His third purchase was made two and a half years ago, and has, up to the present time, ploughed the equivalent of 1640 acres at a cost per acre of:

	s.	d.
Labour	2	5
Fuel and Oil	4	4
Repairs	1	9
Depreciation	2	6
Total	11	0

These figures do not include belt and miscellaneous work, which was not sufficient materially to affect them.

The driver, who has driven all three tractors, is an excellent ploughman but not a mechanic—all except the simplest repairs have to be done by a skilled mechanic; during the life of the present tractor there has been only one stoppage due to mechanical breakdown. The most expensive part of breakdowns is not the cost of repair but the delay to the work of cultivation.

When there is great pressure of work in the summer, two drivers work the tractor 18 hours a day, thereby doubling the daily output of work.

Mr G. R. Hunter (Midland Agricultural College) thought that interchangeable wheels or tyres for the tractor were of great importance. A figure of 90 days per year seemed to be the average working time of the tractor on the land, and even this was not reached in wet seasons. Some simply attached system of rubber-tyred rims for road work, and a suitable trailer, would be very useful as a means of increasing the yearly working time, and especially advantageous to those farmers whose holdings were some distance from a railway station or market. It would reduce, or perhaps obviate, the necessity for a motor-lorry; a non-governed tractor, fitted with brakes to comply with regulations, would, however, be needed.

He thought that the horse had well held its own in the discussion, and suggested that not enough stress had been laid on the great advantages of higher speed and power that the tractor afforded. On the College farm this year they had, thanks to tractors, been able to cross every stubble twice; few Midland farmers were in that fortunate position.

While he agreed that certain tractor implements, being adapted from horse-drawn types, did not adequately utilize the power of the tractor, the modern disc-harrow should be excluded. Properly set, it taxed the tractor to its utmost and did better work than the horse implement.

Mr T. Milburn (Principal, Midland Agricultural College): The relative value of horse and tractor work was a matter of expediency rather than of cost. Just as the best horse-ploughing could not equal spade-work, so tractor-ploughing could not equal the best horse-ploughing; nevertheless, poor tractor-ploughing done at the right time may give better results than good horse-ploughing done too late in the season. To discuss their relative merits only on a cost-per-acre basis was beside the point.

He was sceptical about hitching harrows behind the cultivator so as to give the tractor a fuller load; for the best results were

often obtained when there was a period between the respective operations to allow the ground to dry, weeds to be killed, and weed seeds to germinate. The same objective applied to rotary tillage.

Mr H. Currant (Farm Foreman, Rothamsted) spoke of his experience with the Austin tractor on the Rothamsted farm.

It was valuable for the autumn ploughing of clean stubbles, and in harrowing down before the drill, when the ploughed land was dry enough. The tractor was most useful in the cultivations for spring crops and roots. The land could be re-ploughed and tilled quickly, and the extra depth of cultivation needed for roots could be easily obtained without upsetting the horse work. Further, the tractor could deal with any field needing bare fallowing, and plough and cultivate it as many times as it might require. One could not plough fallow land too much in the summer when the land is dry.

For neatness of ploughing on clover, ley or stubble the single-furrow horse-plough beats the tractor, because it is the same plough following round its own work, and it is "held" by the ploughman; the tractor-plough, being pulled along and guided only by the tractor, cannot be expected to turn out work of the same quality.

Rolling the corn with the tractor is not an ideal job; a big acreage can be covered in a day, but the wheel-marks show below the roller and much of the corn on the headland gets over-rolled. But it will deal really well with a rough piece of uncropped land in the spring or summer; working in the low gear it will take a heavy set of harrows fastened behind the roller if desired. The tractor was unsuitable for drilling, ridging or bouting some of the lighter harrowing, rolling and, if he might use the term, "horse-hoeing": neither could one divide up the horse-power of the engine and use it for so many carts in times like haytime and harvest.

In conclusion he invited the tractor-plough makers to fit a more efficient skim coulter, as one of the chief difficulties in tractor-ploughing was to bury the rubbish. He also urged tractor manufacturers to fit some plugs that will not persist in oiling up, and to provide a more comfortable seat for the driver.

Mr G. A. Barber (Messrs. J. & H. McLaren, Ltd., Leeds): The various papers read to-day emphasize the need for greater economy on the farm. As a means to this end I would advise the more extensive use of machinery. The most up-to-date implements and power units, embodying simplicity and low running costs, must be employed. The use of machinery requiring highly skilled labour is neither advisable nor necessary for farm work to-day. A large proportion of the agricultural machinery produced in this country at the present time is sent to foreign countries where only native

labour is available for operation. Mechanical cultivation may be divided into two systems—namely, the Cable system and the Direct system. In the Cable system the steam engine is being replaced by the motor-windlass, in which Diesel Oil Engines are used as the prime mover. This has reduced the working costs tremendously, and, in addition, provided a power unit weighing 7 tons as against 14 to 17 tons in the case of the Steam Cable Engines. Such a tackle can be worked in the field practically all the year round, and its light weight greatly facilitates its movement from field to field. The Diesel engine has the flexibility of the steam engine, and such complications as magnetos and carburettors—the two parts requiring special care and attention—are eliminated. The fuel costs for ploughing 500 acres, double cultivating 500 acres, also harrowing and rolling 1000 acres, amount only to £75 on medium to heavy soil, the depth of work ranging from 6 in. to 12 in. A variety of implements can be worked with this system, and a series of change-gears permit the implement to be operated at the desired speed, in accordance with the views expressed by Dr Keen.

In the direct traction system, too, the steam engine has been superseded by the internal-combustion engine, the very latest developments being the introduction of the Diesel Engine Direct Tractor. The fuel costs per acre with this tractor are under 1s. when working in average soil—a great advance in economy when compared with the petrol tractor. Simplicity here, again, is the keynote, and as the whole of the mechanism is enclosed—a point stressed by Mr Burford—a long life is assured.

The work I have seen carried out with rotary tillers both in this country and abroad does not lead me to believe that this class of implement will be extensively adopted in this country.

Mr J. E. Newman (Institute of Agricultural Engineering, Oxford): The objections raised by the ordinary farmer to the tractors are usually—(1) difficulty of maintenance, and (2) padding the ground. With regard to maintenance, the most modern tractors have reached a high degree of reliability and with ordinary care should give little trouble.. Much of the trouble experienced in the past has been due to faulty design, and even now there is room for improvement. Farm tractors, under working conditions on many farms, cannot be garaged every night without serious loss of working time, and tractor designers should recognize the fact.

A good deal has been said about the non-mechanical nature of the ordinary farm hand, but there is no reason why agriculturists should include a lower proportion of mechanically minded folk than the rest of the community.

The farm of to-day, apart from tractors, has a lot of machinery. Consider the binder—one of the most complicated bits of machinery

there is. On the mechanical farm of the future, men with a mechanical bent will be as necessary as those with a love and eye for animals on a present-day stock-raising farm.

These objections to the use of tractors apart, the gravest objection most farmers have to it is that it will pad the ground. Our climate and the nature of our soil make this objection a real one, though the ill-effects are often exaggerated. Padding, or compression of the soil, is caused more by the tractive force of the machine than by its dead weight, and it is bound up with the shape of the lugs or strakes and the size of the wheels. Caterpillar tracks have the great defect of heavy cost and of excessive wear. It seems doubtful if these are not inherent in the design, and it is possible that some form of skeleton wheel will be the eventual solution of the difficulty. The Institute of Agricultural Engineering has had the Dawe Wave Wheel under observation for some time, on tractors of varying weights. When these wheels are fitted to a light tractor—such as a Fordson—the wheel-tracks can be harrowed out, and they have the great advantage that when the tractor is being used for general haulage on the farm it can move off soft ground on to a hard farm road, or go through a muddy gateway without slipping.

If further experience bears out our present opinion, they, or some development of the principle, will greatly increase the all-round utility of the tractor. It is this which needs to be increased; the number of hours which many tractors work is far too small, and it is chiefly by increasing the number of jobs which the tractor does that this can be altered. Of course, not only are our implements designed for the horse, but to a large extent farming practice is based on the use of the horses as its main source of power.

Now that a more economical source of the power is available, some of our practices might be altered with advantage. Such alterations will, however, come gradually, as the result of experience. I might mention as an example of greater experience and confidence, that tractors are now used in the hay-field to pull hay loaders. This is now common, but six years ago was hardly heard of. The tractor does this job better than horses, it pulls more steadily, particularly with a big load, and the wheels straddle the window, whereas horses walk on it.

I agree with Mr Bond about steam cultivation. The great weight of the present sets is at the bottom of most of the objections to their use: and that weight is not necessary to prevent slipping. Witness the ability of the M'Laren Diesel Motor Cable sets to work, and their success. At the same time the cable system has probably had its day in this country, and no improvements can be expected to sensibly increase its sphere of usefulness.

As Mr Black said, it is unlikely that one type of general-purpose tractor can do all the work of all farms. Possibly the evolution of the tractor will be in two ways, one being in the direction of a stronger machine capable of easily ploughing three or four furrows in strong land, and used for cultivation work proper and the heavier belt-work—as thrashing—the other being in the direction of a light machine, capable of doing the work of a four-horse team and used for harvesting and drilling and the lighter work generally. Such machines are being evolved, and are necessary if horses are ever to be replaced to any considerable extent by tractors.

Mr J. W. Collis (Tractor Traders, Ltd.): Cost data, while of very great value, is most difficult to compile to apply to all conditions. In making comparisons as between horse and tractor work I do not think sufficient stress is laid on the many jobs the general-purpose tractor can do. I submit that with the "caterpillar" or track-laying type of tractor there is hardly any work on the farm it is not capable of doing.

On the question of electrical power, it is significant that in countries where it is so easily obtainable from natural sources—*e.g.* the "Niagara Peninsula"—it has not been applied to farm work on a far-reaching scale.

Hardly enough stress was laid on the necessity of more draw-bar horse-power in the tractor and the advantage of securing deeper tillage so essential for the cultivation of sugar-beet and other root crops. Direct traction is much cheaper than steam tackle by stationary engines, but the necessary power must be available at the draw-bar without track slippage to do the work. I agree with Mr Deck that to take advantage of the speed and superior draw-bar horse-power of the better type of tractor, and to produce a satisfactory implement to use with it, requires the closest possible co-operation on the part of the tractor manufacturer, the agricultural-implement manufacturer and the agricultural expert.

Captain E. H. Gregory (Rothamsted) pointed out that no comparison was made between roads necessary for lorry work and horse work.

Both the farm wagon and cart are capable of standing the strain of bad roads, and at the same time carrying heavy loads. The lock of the wheels of the modern farm wagon allows it to turn in its own length. The horse is able to get on to other ground leaving the weight of the wagon on the road. An attempt to turn a lorry on a very wet day in a small track will, without doubt, lead to the bogging of the lorry directly it gets on to soft ground. Again, the condition of these tracks is generally so bad that the continued use of a heavily laden lorry on them would not only

make them worse, but would most decidedly shorten the life of the lorry. Lorries in use on such tracks are either of the 7 cwt. or the 1 ton type, and even these have difficulty in negotiating the roads in bad weather.

The question of repairing the roads so that they may be fit for use with motor traffic is one which would involve a great deal of money. In many cases the farmer is bound by his lease to keep his roads in repair. A few cart loads of stones are put down at most irregular intervals in order to fill up the holes, for as long as a farm cart drawn by a horse can proceed along the road, it is in a state of good repair. The main roads throughout the country are gradually being altered in order to stand the extra heavy wear they receive on account of the increase in lorry traffic. It therefore follows that, if this increase is to spread to the farm, the same change, even if on a smaller scale, will have to take place on rural roads, and the question is, who is going to pay for it?

Mr J. M. Bannerman (Agricultural Economics Research Institute, Oxford) stated he had undertaken, under the auspices of his Institute, an examination of the economy of power on the farm, and the resultant effect on the efficiency and standard of living of the farm labourer. The economic evidence put forward, while representing adequately individual examples of actual fact, only serves to draw attention to the necessity of a much wider survey. Issues of deeper significance are also involved. For example, stress is laid in these times on the trend of the efficient agricultural labourer towards the town, and it is one of the crucial questions whether or not this efflux of the best rural worker could be stemmed in proportionate degree to the introduction of machinery. The ideal of obtaining an approximation of rural to urban conditions, both of work and standard of living, is a strong justification for Mr Matthews' advocacy of electrical power on the farm. The recent Electricity Bill should make the availability of this form of power more universally possible.

All the factors that contribute to the efficiency and contentment of the rural worker are of far-reaching importance, and discussions concerning improvements, mechanical and otherwise, on the farm would, I think, be ultimately of greater use were the social and economic point of view kept well to the fore.

Sir John Russell, in summarizing the discussion, said that four main points arose: (1) The need of elasticity in the source of power: in this direction horses were superior; (2) The necessity for getting the utmost out of the source of power: at present horses still retain an advantage here because of the traditional love of the farmer for them, which showed itself in the attention given

to keep the horses fit; but this was a decreasing advantage because with the coming of the bicycle, and later the motor-cycle, into rural life, a mechanical turn of mind was growing up in the countryside; (3) The close adaptation of the implement to the source of power: here, again, the advantage of the horse was declining and improvements in power-drawn implements were constantly being made; this work necessitated the co-operation of the implement manufacturer, the engine manufacturer and the soil investigator; (4) The necessity for keeping up the speed of work so as to be well ahead in all operations: here the tractor was definitely superior, especially as it could do the extra emergency work, which was beyond the capacity of horses.

GENERAL SUMMARY OF PAPERS AND DISCUSSION

By B. A. KEEN, D.Sc., F.Inst.P.

(1) Six forms of power are in use, to varying degrees, on the present-day farm: horses, and engines whose motive power is (*a*) steam, (*b*) gas, (*c*) petrol or paraffin, (*d*) low-grade fuel, (*e*) electricity.

(2) None of the mechanical forms of power is likely to replace the horse in the near future. The horse is very adaptable; a team can be split up and distributed to different kinds of work. The main functions of mechanical power are to provide a reserve of power for heavy and urgent work in cultivations and harvest, and to release horses for haulage work. The general characteristics of each form of power are discussed in the following paragraphs.

(3) *Steam.*—This is the most flexible form of power. Increased load does not "stall" the engine, but merely reduces its speed. It has long been established for deep and rapid ploughings and cultivations, in the familiar cable outfits. The work is done almost entirely by contract, few farmers having enough large areas to justify owning a set. Some difference of opinion exists as to whether the heavy weight of the engines is really necessary; and haulage of water and coal to the engines, and the time spent in getting up steam, are regarded by the farmer as disadvantageous. The development of steam wagons for general road haulage has not yet spread to agriculture.

(4) *Gas.*—Its use is confined to stationary engines, for driving barn machinery, etc. Very few gas engines are in use, and their number is decreasing.

(5) *Petrol or Paraffin.*—Engines of this type constitute by far the greatest number in use on the farm, and their number is constantly increasing, both in the form of stationary engines and tractors. Modern designs are much more economical of fuel and oil than those introduced just after the War, and stoppages due to mechanical defects have been largely overcome. Stationary engines are used for barn machinery, although the tractor is commonly employed for the heavier belt-work, in addition to its use in hauling binders and cultivation implements. Its use for road haulage has hardly begun as yet.

(6) *Low-grade Fuel.*—Heavy oils and low-grade fuel can be successfully utilized in the Diesel type of engine with the double reduction of fuel costs and depreciation, because of the simpler

form of engine, fewer moving parts, and lower temperature of ignition. The use of Diesel-type engines for cable-tackle sets is now an accomplished fact, and a successful form of light tractor also is said to be in use.

(7) *Electricity.*—The electric motor is by far the simplest form of prime mover. There are only the two main bearings and the brush-holders requiring occasional attention, and no mechanical aptitude on the part of the worker is necessary. The necessity for a cable that has to be wound and unwound as the implement passes across the field is a drawback for cultivation work, and a grave difficulty is the necessity for a storage battery or petrol engine for independent motive power.

(8) It appears that steam-power will continue in use for heavy cultivation work, but may be seriously challenged by the Diesel engine; on the other hand, the steam wagon may be developed for haulage of farm produce to market. The paraffin or petrol tractor will for some time be the most general form of farm power for belt-work, cultivations, harvest operations, and perhaps road haulage. Electric-power can increase only with a spread of electrification of the rural areas, and the heavy cost of overhead lines, due to stringent safety precautions, is a serious obstacle. Calculations indicate that the total rural load would be economic, while electric light in the homes and in the farm-buildings would add to the comfort of the workers, and improve their efficiency. The petrol-electric system, that aims at combining the advantages of electric drive with the independence from fixed cables of the petrol engine, appears worthy of serious attention.

(9) There is general agreement on the design and specification of the general-purpose tractor—*i.e.* the machine for the average farm, where one only, or at the most two, would be employed. It should be of the light type, weight about 30 cwt., centre of gravity near centre of wheel-base and as low as possible; 22-30 h.p.; revolutions not exceeding 1200 per minute; strong and efficient radiator; gear drive fan and water pump; governed engine; magneto ignition; forced lubrication; strongly designed crank-case; accessibility to all parts needing adjustments; dust-proof ball or roller bearings; gears machine-cut and heat-treated, and of the highest grade material; rear axle of strong design, and front axle sprung and pivoted; two forward speeds and reverse, and efficient brakes on rear wheels for road haulage; fitted with oil filter and air clarifier; adjustable draw-bar, pulley for belt-work, and independent power take-off for direct coupling to machinery; speed and power to drive full-size thrashing machine; facilities for rapid conversion of wheels from farm work to road haulage, and *vice versa*; protection for driver from dust, etc., and a comfortable seat.

(10) For larger farms, especially those on heavy land, the

general-purpose machine is not so suitable as two separate types: one a heavy tractor for three- or four-furrow ploughing, and the second of lighter design for cultivating, belt-work, etc.

(11) The general-purpose tractor is used for about 300-700 hours yearly, as against 1700 hours or more for the horse. The average cost is about 3s. per hour of work; the corresponding figure for the horse is $5\frac{1}{4}$d. This comparison does not take into account the extra speed and power of the tractor, enabling it to do more work per hour. On a cost-per-acre basis, where these factors are included, the tractor is cheaper than horses for ploughing, but dearer for all other forms of cultivation.

(12) Where the tractor is given a full load, therefore, its cost of operation compares very favourably with horse-power. The present forms of tractor implements—with the possible exception of ploughs—do not give the tractor a full load, and the practice of hauling implements in tandem—*e.g.* two binders, or harrows following cultivators—is not always possible, and certainly not convenient, with present designs.

(13) At present the tractor finds its chief outlet in ploughing after harvest, spring ploughing and cultivations, haulage of binders and driving of thrashers. It is of the utmost value, especially in times of pressure, and even if the cost of operation were much higher than it actually is, it would amply repay this by its ability to get work done at critical times.

(14) The design of tractor-drawn implements, with few exceptions, has not kept pace with the development of the tractor. This is perhaps the chief factor limiting its more extended use on the farm.

(15) There are suggestions from practical men that the tractor plough should be improved: a two-furrow one-way type is advocated, linked on to the rear of the tractor and not hooked on to the drawbar. The linkage would have to be such that a reasonably constant ploughing depth was maintained on uneven land. The ordinary skim-coulter also is said to be unsatisfactory. The disc harrow is said to be very suitable for tractor work. The killing of weeds is a most important object in cultivation operations, and if implements were designed with this aim more specifically in view it is possible that the actual number of operations now considered necessary to produce a tilth could be reduced.

(16) The use of combined tools, of the rotary cultivator type, is now well established for light market-garden soils. For ordinary agriculture they are still in the experimental stage. Since the aim of this machine is to produce seed-bed in one operation, the problems of soil tilth are of special importance. The use of a light machine that, with suitable attachments, could hoe and cultivate between the rows of root crops is a possible development of considerable promise.

(17) The use of the tractor for road haulage of farm produce is, apart from the general question of suitable rural roads, dependent upon (*a*) some simple and rapid attachment for conversion of land wheels to road wheels, or *vice versa*; (*b*) increased speed. Since rubber-shod wheels are practically standard equipment for road vehicles, and since, for land work, a proper grip is essential to prevent slipping and loss of effort, it appears that both rubber blocks, and strakes or spuds, must be provided, in a readily interchangeable form. Although there are some promising designs, they are still in the experimental stage. The track-laying or caterpillar track has not yet found extended favour in this country; neither has the four-wheel drive. The latter is worthy of fresh attention from designers.

Increased speed of work would be of great use for cultivations as well as road haulage. It has been shown that, as far as the soil resistance alone is concerned, the extra draw-bar pull needed increases much more slowly than the speed of work. Although, in addition to this, there would be increased power needed to propel the tractor itself at the higher speed, it appears that the limit of compromise between speed and durability has not yet been reached.

(18) The traditional policy of laying down land to grass in periods of agricultural depression may need revision, in view of the great developments in the imported-meat trade. One alternative would be an intensification, in suitable areas, of arable farming in which special attention would be devoted to vegetable products of a semi-market-garden type, whose culture would call for the extended use of power farming methods.

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PAPERS

HORSE AND MECHANICAL POWER IN FARM OPERATIONS

By B. A. KEEN, D.Sc., F.Inst.P.

Assistant-Director Rothamsted Experimental Station

The advent of mechanical power on the farm began in the middle of last century, when steam-power was first applied to cultivation. The agricultural Press of that period—particularly the *Journal of the Royal Agricultural Society*—bears much evidence of the high hopes entertained for this innovation. The enthusiasm was not without reason, for everything pointed to a long period of abounding prosperity in agriculture; in fact, the decade 1852-1862 has since been known as "the golden age of English farming." It was succeeded only too soon by the great depression that began in the late 'seventies, and it is significant that steam cultivation weathered this period of stern trial, and still remains to-day an established practice. But its struggle for survival clearly showed that its true position was an adjunct to, and not a substitute for, horse labour. Steam-power came to stay as a valuable aid in rapidly breaking heavy land in the autumn, and for deep spring cultivation—especially for crops like potatoes, that respond to a deep tilth.

In more recent years the internal-combustion engine has rapidly extended into agriculture, and the situation that arose when steam-power was introduced has emerged again, only in an intensified form. In the first place, the petrol or oil engine is a lighter unit than steam tackle; it is thus more comparable to the horse for ordinary farm work, and its cost permits the average farmer to purchase it, whereas he must put his steam work out to contract, with the risk that it will not be done at the most convenient time. In the second place, the internal-combustion engine has revolutionized road transport and haulage methods, and may do the same for farm haulage.

The latest information shows that the use of power for all purposes is steadily, or rather rapidly, increasing on the farm, in spite of the great depression of the past years: the extent can be seen from Table I., taken from *The Agricultural Output of England and Wales*, 1925, published in 1927 (Cmd. 2815. H.M. Stationery Office).

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TABLE I

NUMBER OF AGRICULTURAL ENGINES RETURNED AS USED IN:

	1908	1913	1925
(a) *Fixed or portable—*			
Steam	8,690	7,719	3,731
Gas	921	1,287	1,125
Oil or petrol . .	6,911	16,284	56,744
Electric . . .	146	262	700
(b) *Motor tractors—*			
Field work . . .	...	...	14,565
Belt work (only) . .	...	...	2,116

The returns were voluntary; it is estimated by the Ministry of Agriculture that these represent about 75 per cent. of the engines in use. The increase in petrol engines is very great, and is far more than the decrease in other forms. Again, there were too few tractors to be recorded in 1913; in 1925 there were more than 16,500. It is evident that the internal-combustion engine has come to stay in agriculture, and our task in this Conference is to discuss to what extent it seems likely to replace horses, and to outline, on the basis of our present experience and information, those directions in which further improvements are needed.

The subject is twofold; it involves both technical and financial considerations, and, although they are so closely interwoven in practice, it is better for discussion to separate them as far as possible, and to take the financial side first. We have much information in our own farm records at Rothamsted, that Mr Garner has kindly summarized for me, and various departments of agricultural economics in the country have willingly given me additional data from their own detailed costings investigations.[1] The figures are in general agreement, and may be taken as reasonably close estimates of the costs of tractor and horse operations on the typical mixed farms where the arable area is not less than 40 per cent. of the whole, and is usually more.

Before considering the costs of different operations—*e.g.* ploughing and cultivating (with either the horse or the tractor)—it is desirable and instructive to see the general average cost for all work with each form of power. We will take horse-power first. In theory

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TABLE II

COST PER HORSE-HOUR IN PENCE, EXCLUDING IMPLEMENT DEPRECIATION AND REPAIRS

Year	*Rothamsted*	*S.E. England*	*Eastern Counties*
1923-1924 .	7·75[1]	5·11	4·62
1924-1925 .	...	5·33	5·08
1925-1926 .	6·75	5·56	4·94
1926-1927 .	...	...	5·95

These figures refer to widely different soil types and cropping systems, but are sufficiently close together to make the average of some significance. The somewhat high figure for our own farm is explained by the presence of several hundred experimental plots. Although the accounts for these are kept separate from the normal farm operations, they have to be worked by substantially the same staff and farm equipment. This arrangement is both inevitable and costly, not only for the experimental plots but the rest of the farm, and it is surprising that the figure is not much higher.

The original figures for the Eastern Counties included implement repairs and depreciation, and as the cost of this was not given separately, the round sum of 3d. per horse-hour was deducted to give the values in Table II.; our own figure was 3·44d., and seemed rather too high.

It appears, therefore, that a fair average cost per one horse-hour is about 5¼d. This figure includes cost of food, less credit for manure produced, cost of shoeing, veterinary service and medicine,

[1] Includes much hired horse labour, which is notoriously expensive.

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The next step is to obtain a similar figure for the tractor, and this is more uncertain, as few costings have yet been made. In Table III. are some collected results.

TABLE III

COST PER TRACTOR-HOUR, EXCLUDING IMPLEMENT DEPRECIATION AND REPAIRS

Year	*Rothamsted*	*S.E. England*
	s. d.	*s. d.*
1922-1923 . .	3 6½	...
1923-1924 . .	5 5	3 2
1924-1925 . .	3 3	2 8
1925-1926 . .	3 3	3 1
1926-1927 . .	3 3	...

These figures include tractor depreciation, fuel and oil, repairs, and a few sundries, but do not include implement depreciation and repairs and driver's wages, except in the Rothamsted figures, where the commissions paid to the farm-hand acting as tractor-driver are included, and amount to just 10 per cent. of the total cost per tractor-hour.

A figure of 3s. per tractor-hour is probably not far away from the average cost, although in the figures from which Table III. was constructed there were, just as in Table II., very wide variations in cost from farm to farm.

However, on a reasonably equal basis of comparison, we may say, with fair accuracy, that a horse-hour costs 5¼d. and a tractor-hour, 3s., —or nearly seven times as much—and to this must be added the difference between the hourly rates of wages for horsemen and tractor-drivers.

This comparison is based on the total work of all kinds that the horse and the tractor perform on the farm, and too much weight must not be placed on it. It has been arrived at by a drastic process of averaging, and it includes not only widely different types of work but different systems of agriculture, and varying degrees of skill in management. Still, as a general over-all figure, it gives some precision to the comparison of the two forms of power.

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1926-1927 . .	3	3	...	

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The next information desirable is the relative costs of tractor and horse for the same kind of work. A certain number of comparisons for work on the same farm are available. These are collected in Table IV. on a basis of costs per acre, and include also some tractor figures for which horse-figure comparisons are not available.

TABLE IV.

COST PER ACRE FOR HORSE AND TRACTOR, INCLUDING WAGES

	Rothamsted	*South East*	*East*	*South West*
Ploughing—				
Horse . .	20/-	19/10, 14/10, 17/2	...	...
Tractor . .	15/9	14/6, 11/11, 8/-	13/7	(18/5), 11/-
Cultivating—				
Horse . .	2/6	4/	...	...
Tractor . .	3/6	4/5	3/6	...
Harrowing—				
Horse . .	1/6			
Tractor . .	3/6			
Rolling—		...	2/7	...
Horse . .	1/6			
Tractor . .	2/1			
Harvest—				
Horse . .	2/7	2/8, 2/1	...	...
Tractor . .	3/11	3/6, 4/7¼	4/3½	...

Here again, although there are appreciable variations, the general run of the figures is sufficiently close for our purpose, and we may now proceed to discuss the bearing of these costings figures on the technical and practical questions.

The first question that arises is an obvious one: Is the tractor likely to replace the horse as the main source of power in British agriculture? At first sight it appears equally obvious that the answer is a definite negative, since from Tables II. and III. we have seen that a tractor-hour is seven times more costly than a horse-hour. But the question is not so simple: the cost per hour is decreased if the number of hours worked is increased. At present the tractor on the average farm is used for 300 to 700 hours per year, while the horse puts in at least 1700; so there is ample opportunity for reducing the cost of a tractor-hour, if the practical

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Tractor . .	3/6			
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problems of using the machine on the farm to a greatly increased extent can be solved. In addition to this there is the certainty that the present-day running costs of a tractor will be reduced by improvements in design and by better care of the machinery. The distribution of the charges over the various items shows that, at present, fuel and oil account for about 50 per cent. and repairs and depreciation for 50 per cent. Beyond remarking that this indicates the responsibility for improvement, which lies equally on the manufacturer and the user, we shall not discuss it further, as other papers will deal with both these matters in detail. However, the improvement already achieved is shown by the two figures for S.W. England in Table IV. These were obtained on the same farm. The higher cost (in brackets) refers to a tractor working during 1922-1925, and the lower cost to a present-day model.

The second question that arises is: Assuming that the tractor is to be used mainly as an addition to horse labour, in what direction can it best help? Table IV. gives important information: the costs per acre in ploughing are appreciably cheaper with the tractor than with horses. In all other operations the tractor is dearer, but it need not necessarily be so. Ploughing is cheaper because the tractor is working at or near its maximum capacity, while in the other operations its load is too light. Until some mechanical genius builds an extensible tractor on the "unit" principle we must aim at increasing the load. The farmer can do this to some extent with his existing implements. Two binders can be hauled in tandem, harrows can be hitched behind cultivators—if the condition of the ground permits—and so on. But these are makeshift arrangements, for the setting of the front implement has often to be altered because of the drag behind it, and a wider headland also is needed for turning. There is scope here for the implement maker.

Up to this point we have based the comparison of horse and tractor work entirely on costs of operations. But the great advantage of the tractor is its power and speed, and its ability to work for long periods. It enables rush periods to be dealt with so that the work can be kept well ahead. The results are reflected in the final yield and the financial returns, but it is almost impossible to manipulate the figures to show the part played by the tractor. Unfortunately, in our climatic conditions the farmer knows only too well the results of a short enforced delay at a critical period, and has no doubts whatever about the advantage of being well ahead with his work.

This aspect can best be seen by taking a few typical examples:

(a) *Autumn Cultivation in Dry Weather.*—The important operation of stubble-breaking in these conditions often necessitates adding extra horses to the team, thus slowing up the harvest and carting. The tractor easily deals with the work.

problems of using the machine on the farm to a greatly increased extent can be solved. In addition to this there is the certainty that the present-day running costs of a tractor will be reduced by improvements in design and by better care of the machinery. The distribution of the charges over the various items shows that, at present, fuel and oil account for about 50 per cent. and repairs and depreciation for 50 per cent. Beyond remarking that this indicates the responsibility for improvement, which lies equally on the manufacturer and the user, we shall not discuss it further, as other papers will deal with both these matters in detail. However, the improvement already achieved is shown by the two figures for S.W. England in Table IV. These were obtained on the same farm. The higher cost (in brackets) refers to a tractor working during 1922-1925, and the lower cost to a present-day model.

The second question that arises is: Assuming that the tractor is to be used mainly as an addition to horse labour, in what direction can it best help? Table IV. gives important information: the costs per acre in ploughing are appreciably cheaper with the tractor than with horses. In all other operations the tractor is dearer, but it need not necessarily be so. Ploughing is cheaper because the tractor is working at or near its maximum capacity, while in the other operations its load is too light. Until some mechanical genius builds an extensible tractor on the "unit" principle we must aim at increasing the load. The farmer can do this to some extent with his existing implements. Two binders can be hauled in tandem, harrows can be hitched behind cultivators—if the condition of the ground permits—and so on. But these are makeshift arrangements, for the setting of the front implement has often to be altered because of the drag behind it, and a wider headland also is needed for turning. There is scope here for the implement maker.

Up to this point we have based the comparison of horse and tractor work entirely on costs of operations. But the great advantage of the tractor is its power and speed, and its ability to work for long periods. It enables rush periods to be dealt with so that the work can be kept well ahead. The results are reflected in the final yield and the financial returns, but it is almost impossible to manipulate the figures to show the part played by the tractor. Unfortunately, in our climatic conditions the farmer knows only too well the results of a short enforced delay at a critical period, and has no doubts whatever about the advantage of being well ahead with his work.

This aspect can best be seen by taking a few typical examples:

(a) *Autumn Cultivation in Dry Weather.*—The important operation of stubble-breaking in these conditions often necessitates adding extra horses to the team, thus slowing up the harvest and carting. The tractor easily deals with the work.

(b) *Autumn Cultivation in Wet Weather.*—On heavy land in a wet autumn speed is essential if the work is to be done before winter sets in. The tractor can work the binder at high speed and for long hours, setting free horses for carting and cultivations.

(c) *Spring Cultivation.*—After a wet winter, and in a rainy spring, the intervals between a sodden state of the soil and a condition too dry for proper working are very short, and considerable areas have eventually to be pulled down into a "forced" tilth. The tractor can cope with the rush of work, thus increasing the area of land in good tilth.

Many other instances could no doubt be mentioned, and, when it is remembered that these advantages are also given by a machine that on heavy work compares very favourably with horse costs, a strong case is made out for the employment of a tractor on the average farm.

In addition to cultivation and harvesting work, the use of mechanical power on the farm will certainly increase. This is especially true of general haulage work, both on and outside the farm. The actual costs of this work can be well illustrated by a recent example. An Eastern Counties farmer has kept careful figures, and finds that collecting sugar-beet off the field, carting on main road to a station one and a half miles away, and unloading into trucks, costs him about 4s. per ton. If there is any congestion at the station the cost rapidly increases, and may reach easily 8s. per ton. In addition to this he loses the use of his horses for other work for three of the most important months of the year.

Some form of tractor that will pull larger loads at a greater speed than horses is a self-evident alternative. This implies some easily fixed form of road-bands for the wheels or, alternatively, easily removable strakes. Increased speed is also desirable, not only for road work but for cultivations as well. We have shown at Rothamsted that the soil resistance increases only slowly for a considerable increase in speed of working. Hence, there would be a further economy in land work if the tractor were designed to run at increased speed. Obviously some other factor might have to be sacrificed, or reduced, and the designer would have to make the best compromise, remembering that a working speed undesirable on purely technical grounds may have very distinct practical value.

Any advance of this nature also concerns the implement makers, since the proposed speed of an implement is one of the many factors to be taken into account by the designer. In fact, the general problem of tractor-implement design and construction —at first necessarily an adaptation of existing horse implements— can hardly be regarded as solved. They are designed largely

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as separate units to be hooked on to the draw-bar; they are merely drawn by, and in no sense an integral part of, the machine. There is scope here for improvements, and at least one form of plough is now on the market designed for coupling direct on to a tractor. The advantages of easier control by the driver, ability to do neater work, and saving of space at the headlands would be fully appreciated by the farmer.

It is but a short step in theory from a series of cultivation implements that are definite attachments to the rear of a tractor to a single tillage machine that will produce a tilth at one operation. Much work is being done on rotary cultivation in an endeavour to solve the many practical problems of soil tilth. We shall not deal with this; it is the subject of another paper to-day, and our own experiments have already been discussed by the writer at an earlier conference on Cultivation. One aspect, however, must be mentioned. A rotary cultivator and its engine form a single machine, and although it could do belt-work also, it could not in its present design perform haulage work, and serve as a general-purpose machine to the extent that the tractor does.

The directions in which mechanical power will extend on the farm in the immediate future are unmistakable, and the salient features of the machine and its accessories can be written down: a tractor of 10-20 or 15-30 h.p., weighing about 30 cwt., fitted with a belt pulley and a power take-off for direct driving of binder machinery, etc.; a range of cultivation implements, not simply hooked on the draw-bar but properly coupled and closely under the driver's control; the maximum speed consistent with reliability; strakes easily and quickly removable, or covered with a band for road work (or possibly some form of caterpillar tread); and, finally, general reliability and a long working life.

To use such a machine to the best advantage is the farmer's task. He must give it the same attention bestowed as a matter of course on his horses. He must so arrange his horse and tractor work that each gets the type of labour for which it is best fitted, and, above all, he must exploit to the full the capacity of the tractor to do heavier work than horses, at a greater speed, and for a longer time.

Finally, investigation is urgently needed on such matters as deep ploughing, subsoiling and rotary tillage. The tractor has placed the means of doing these operations at our disposal, but we have very little information indeed about the best methods of doing the work, the most suitable designs of implements, and, above all, of the effect on the soil—which, after all, is the most important thing. This forms an important part of our work at Rothamsted. We are studying in the laboratory and in the

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field under practical conditions the problems of soil tilth, on which developments of the above nature must be based.

In this brief review of the subject the endeavour has been made to compare and contrast horse and tractor work on the basis of actual performance alone, and the evidence leads to the definite conclusion that mechanical power will, on its merits, play an increasing part in our farming operations.

There are two other factors that will in all probability accelerate this process.

The first is: market for draught horses is rapidly diminishing with the greatly increased use of motor transport, and we seem to be within reasonable distance of the time when the farming community itself will be the only buyers of horses.

The second point is perhaps more debatable, but one wonders whether the traditional method of meeting bad times by taking land out of cultivation and laying it down to grass is going to survive the great development of the cheap imported-meat trade. Farmers met the competition of imported wheat in the 'seventies by laying land down to grass; they may be compelled to meet the competition of imported meat by maintaining their land in arable crops, in which prominence will be given to semi-market-garden crops, for which there is, throughout the country, a large and increasing demand.

THE DESIGN OF A GENERAL-PURPOSE TRACTOR

By H. G. BURFORD, M.I.A.E., M.I.Mech.E.

S. Hampstead

Before dealing with details bearing on the subject of the "General-Purpose Tractor," I think it would be of value to review the development of the Tractor industry that has been steadily taking place during the last two or three years. Unfortunately for all interested, the agricultural industry in this country has gone through very difficult times, and the general position is one of great anxiety. Whilst countries on the Continent are steadily developing the use of the tractor—covering very wide fields of activity, and absorbing them in large numbers—the home requirements are very small and, again unfortunately, supplied very largely from foreign factories. This state of affairs is very regrettable, and when the demand comes from the British agriculturist—as it is bound to do—Britain will

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find great difficulty in meeting that demand. In my opinion—which has not changed for many years—the way to restore prosperity to the agricultural industry must be by the employment of mechanized power for every possible requirement on the farm. This opinion is based on the first and important question of *time*, and the necessity —owing to the various climatic changes—of using every available opportunity for intensive cultivation.

The manufacturers of tractors in the past have been met always with the question of producing tractors at a low price, and in many cases to meet these conditions it has necessitated the employment of unsuitable material, with results quite frequently very unsatisfactory to all concerned.

It has been found by experience that to give satisfaction it is imperative that material of the highest quality only should be used.

Assuming that the tractor of to-day embodies high-grade material, with all the advantages of heat treatment and the results of steel research derived from experience gained both during the War and after; and remembering that many manufacturers of tractors are also manufacturers of cars and commercial vehicles, and with their extensive production methods and modern machinery can bring into the tractor business their experience, thereby reducing the cost to a minimum; whilst other firms specializing on the production of tractors in specially equipped shops also have practical experience in productive methods in other branches of their business; based on these facts, the agriculturist, when purchasing a tractor, can be assured that all the ingenuity and skill of the engineer, both as to material and workmanship, are embodied in their latest products.

The question of maintenance and upkeep is being separately dealt with by Mr Watson, so that my remarks will be brief. The extreme conditions under which the farm tractor has to perform its work calls for care and attention from the hands of the user: cleanliness, care of entire lubrication system, periodical inspection and adjustment of all wearing parts, careful attention to all the instructions issued by the manufacturer, and good housing accommodation. Neglect of all or any of these points will be costly, and the results will be dissatisfaction to both user and manufacturer.

Practical experience and study have proved that the worst enemies to the agricultural tractor are dust, grit and lack of attention. Manufacturers are giving great care and study to eliminate the foreign matter from the engine. Not long since it was the general practice to take the air in through the carburettor by means of an open pipe; this led to excessive engine wear. Many devices have been tried, including water filters—*i.e.* the air being sucked through a volume of water. This, however, was unsatisfactory from many points of view, and has been discarded. Trials have

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been made with an apparatus fitted with felts of various dimensions and sizes; this system failed for the reason that the operator did not change the felts often enough, and the finest particles were drawn through into the engine, naturally causing great damage. One leading manufacturer of to-day still retains the felt cleanser, but of generous proportions, owing to the position of the radiator. It is realized by experience, which has been gained in countries in Europe where conditions of long periods of drought exist, that to make a tractor at all practical and efficient an air clarifier and oil clarifier are indispensable. The present practice is for an apparatus to be fitted that can be removed easily and cleaned, and in which the air passes over or through a series of plates that have been dipped in oil. At the beginning of each day's work the plates—which are in the form of a cartridge and easily removed—are washed out by paraffin; they are again immersed in oil and replaced. This operation takes very little time, but the results in the reduction of wear on cylinders, pistons and other working parts are remarkable, and will give a much longer life to the most important part of the tractor—the engine.

Another important feature is the filtering of the lubricating oil from the sump of the crank-case. The oil passes through a filter, fitted with felt pads or coils. In this way the oil is cleaned of all foreign matter before being again pumped through the main oil channels. The results of this system add longer life to all wearing parts.

General-Purpose Tractor.—In laying down a definite specification for the above tractor, consideration must be given to the various conditions and requirements that are met with in the various parts of the world; and it is only by close study and careful analysis of these conditions that I am endeavouring to outline what in my opinion a tractor should embody to serve a useful purpose in the agricultural world. The tractor for general purpose on the average farm, in my view, should be of the light type—22 to 30 horse-power, at revolutions not exceeding twelve hundred per minute; four cylinders; good, strong and efficient radiator; gear drive fan and water pump; governed engine; magneto ignition; forced lubrication; crank-case to be of strong design; easy access to all parts requiring adjusting; ball-bearings to be made as dust-proof as possible; two speeds and reverse; all gears to be machine-cut and of highest-grade material, heat treated; rear axle to be of strong design; ample brakes to be fitted on rear wheels for use when on road haulage; weight not to exceed 30 cwt.; to have belt-power and speed capable of driving full-sized threshing-machine or any other implements used on the farm; adjustable draw-bar; facilities for changing spuds or strakes quickly and replacing with solid twin-tyres on rear wheels, single on front without change of wheel; to

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be fitted with an air clarifier and oil filter; the front axle to be sprung and pivoted, capable of movement to accommodate wheels on irregular surfaces—in general, a tractor that can be operated easily, economically, and be capable of use for all the various requirements of farm work in general.

There is, of course, a field for tractors of a large horse-power and of a heavier type, but a tractor on the above lines will be found quite sufficient for the average requirements of the agriculturist.

Implements for use with the Tractor.—There is still much to be desired in the question of co-ordination of interests between the implement manufacturer and the tractor maker. At a very important demonstration under the auspices of the French Ministry of Agriture, in October 1927, it was observed that where the implements were doing bad work the blame was put on the tractor, and it was at once condemned. Whereas, actually, the tractor was performing its function of drawing the implement, but the implement was totally unsuitable for the work it was called upon to do. Developments of improved ploughs for tractor use are taking place in France and Germany. The advantages are many: ease of control; mounting close to and integral with the tractor; automatic self-lift; one-way operation; and over-all length of tractor and plough reduced to a minimum.

A few figures of the growth of the tractor use in America since the War may be of interest. The figures below are taken from an official statement made to the Pennsylvania College of Agriculturists:

In 1924 there were in use in that state 18,467 farm tractors and 452,000 horses. Assuming 1 h.p. for each horse and 10 h.p. for each tractor, the horse provided 71 per cent. of the draw-bar horse-power, and the tractors only 29 per cent. The figures given for 1924 compared with 1920—for tractors—show an increase of 224 per cent., as in 1920 the numbers stated to be in use were approximately 5697. The official statement also quotes that savings were effected by the use of tractors, the cost in ploughing being 1 dollar 75 cents. per acre. Given a ten-hour working day the tractor will plough approximately five acres, where the work done by a pair-horse team is approximately two acres. Cotton growers state that on a two-hundred-acre plantation the cost of the tractor can be saved in one year as compared with similar work done with a four-horse team.

In conclusion, it is of the highest importance for the future welfare of this country that every help and encouragement should be rendered to the agriculturist to use mechanical power on the farm. The modern tractor can and will do the work required at lower cost, saving of time, and with increase of crop. In the interest of British agriculturists I trust that the responsible authorities

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will give a strong lead to the extended use of the tractor in this country, which will restore the agricultural industry to its right and proper position and so benefit the community at large.

THE CARE OF THE TRACTOR ON THE FARM

By G. W. WATSON, M.I.Mech.E., M.I.A.E.
50 Pall Mall

An agricultural machine or implement usually suffers from the simple fact that it is an inanimate object—*i.e.* it is without life or soul. Whilst most owners will give some measure of personal attention to even the meanest and least profitable animal on a farm, there are many who, having bought a machine, turn it over to a heavy-handed individual who has no knowledge of its construction, no interest in its success, and little or no inducement to acquire that knowledge or stimulate an interest.

Tractors may be divided, roughly, into two broad classes—firstly, the petrol or paraffin class; and, secondly, the steam class. I propose to confine my remarks to the former.

If an engine starts up at the first swing and runs with a healthy purr, indicating that all is well, a driver feels that he has made a good start for the day. This feeling of satisfaction is amplified if the engine answers to the throttle, and pulls in the field as though it took a real interest in its work. In the case of an engine that has been in use for any length of time these results are not obtained without trouble, but it is surprising how long an engine will keep in good condition if it receives consistent attention, and all adjustments are carried out as soon as they become necessary. Apart from the actual breaking of a vital part the diseases from which an engine suffers can be classified, roughly, under the general name of troubles, as follows: ignition, fuel supply, lubrication, valves, and water circulation. To this list of evils may be added knocking or noisy sounds, which are not evils in themselves but are simply warnings that all is not well.

Ignition.—It is of vital necessity to keep the coil or magneto free from damp, because if the condenser becomes damp it will not only cause leakage and failure of the ignition but will not hold any charge, and the resulting spark will not be efficient. Great care should always be taken to avoid spilling water over either coil or magneto, and should any be spilt thereon it should at once be

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By G. W. WATSON, M.I.Mech.E., M.I.A.E.
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An agricultural machine or implement usually suffers from the simple fact that it is an inanimate object—*i.e.* it is without life or soul. Whilst most owners will give some measure of personal attention to even the meanest and least profitable animal on a farm, there are many who, having bought a machine, turn it over to a heavy-handed individual who has no knowledge of its construction, no interest in its success, and little or no inducement to acquire that knowledge or stimulate an interest.

Tractors may be divided, roughly, into two broad classes—firstly, the petrol or paraffin class; and, secondly, the steam class. I propose to confine my remarks to the former.

If an engine starts up at the first swing and runs with a healthy purr, indicating that all is well, a driver feels that he has made a good start for the day. This feeling of satisfaction is amplified if the engine answers to the throttle, and pulls in the field as though it took a real interest in its work. In the case of an engine that has been in use for any length of time these results are not obtained without trouble, but it is surprising how long an engine will keep in good condition if it receives consistent attention, and all adjustments are carried out as soon as they become necessary. Apart from the actual breaking of a vital part the diseases from which an engine suffers can be classified, roughly, under the general name of troubles, as follows: ignition, fuel supply, lubrication, valves, and water circulation. To this list of evils may be added knocking or noisy sounds, which are not evils in themselves but are simply warnings that all is not well.

Ignition.—It is of vital necessity to keep the coil or magneto free from damp, because if the condenser becomes damp it will not only cause leakage and failure of the ignition but will not hold any charge, and the resulting spark will not be efficient. Great care should always be taken to avoid spilling water over either coil or magneto, and should any be spilt thereon it should at once be

mopped off, and, if necessary, dried off by warm air from a lamp or stove, but care should be taken not to raise the temperature of the part so much as to melt the wax or shellac insulation.

I will now deal with some of the more common troubles experienced with ignition systems:

Misfiring.—The driver who knows his engine occasionally detects an alteration of its note or an interruption of its regular hum. This, if accompanied by a falling-off in power, is probably due to occasional or persistent missing of one of the plugs. When compression taps are fitted it is easy to locate the faulty plug. If all the plugs are firing badly, the fault may be either in the petrol supply or in the ignition. If only one plug is missing, the trouble can at once be set down to ignition alone, or, on rare occasions, to a valve being stuck open.

Faulty Plugs.—Apart from actual damage to a plug by breaking the porcelain or other insulation, there are three main evils from which it may suffer. Short-circuiting may take place between the points and the body, due to the hot spark having melted the metal. The gap of the plug may be too wide; it should not be more than about $\frac{1}{50}$th of an inch, or, roughly, the thickness of the average thumb-nail. If the engine misses when running at small-throttle openings the points of the plugs should be set a little farther apart, whereas, if missing takes place at full-throttle openings the points should be set closer together. The third evil is due to sooting up, and is cured by cleaning with a little petrol.

An occasional cause of missing is through having the points set in a pocket in the valve cap. This pocket remains full of spent gas left during the exhaust stroke, and a considerable improvement can be obtained by fitting plugs with a longer reach.

The Magneto.—The magneto may be the cause of irregular firing in any or all of the cylinders, but tampering with a magneto is a pastime not to be recommended unless a driver understands it. There are two points, however, to which occasional attention is required, these are the high-tension distributor and the contact breaker. This distributor disc should be cleaned occasionally with a cloth and a little petrol, and the disc wiped over afterwards with a trace of oil. The contact breaker is the most important part of the mechanism. The space between the platinum points when they are separated should be about $\frac{1}{64}$th of an inch, and any variation from this may cause ignition trouble. The contact points should be trimmed when necessary with a very fine file, so that they bend together level when closed, but they should not be trimmed unless the points are uneven. Oil should not be put on the platinum contacts, or it will cause them to burn away rapidly, Occasionally the lever to which the moving point is attached works stiffly, allowing the points to remain apart; in such a case the fibre bush should be

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eased slightly. Oiling is of no use, as it may make it swell more. If these various points receive proper attention, there is little to go wrong.

A few warnings concerning magnetos:

Don't run the engine with a plug wire disconnected—you may ruin the insulation. If you want to cut out a cylinder, short-circuit the plug—that is, connect it directly to the metal of the engine.

Don't swamp the magneto with oil—two or three drops of good oil once a week are sufficient.

Don't oil the contact breaker.

Don't use an oil-can with dirt on the spout.

Don't file the contacts more than is absolutely necessary.

Don't hold the contact breaker to prevent the spindle turning when tightening up the nut of the driving coupling.

Don't fail to see that the earth wire is not making a short-circuit.

Don't hang plug cables on the exhaust pipe.

Don't replace plug wires on the wrong terminals.

Don't tamper with a magneto unnecessarily.

Motor Fuels.—Every driver knows that if petrol is poured on the hand it evaporates with a marked cooling effect, due to the petrol extracting heat from the hand. In a carburettor, fuel is supposed to be split up into a fine spray, and the heat for its vaporization is extracted from the air. Any cracks or leaks in the pipe which heats up the air to the carburettor should be repaired at once.

The jets in a carburettor are usually very small, and it is very necessary that all the fuel should be carefully filtered before it is put into the tank; as an additional precaution there should be a filter between the tank and the carburettor. These filters should be cleaned regularly, and any drops of water found therein carefully blotted up.

"Popping back" into the carburettor indicates a weak mixture, and is one of the first symptoms of fuel-supply trouble. Such a mixture burns slowly, and may still be burning when the inlet valve opens, thus allowing some of the burning gas to rush back into the carburettor. If the engine has been running normally and popping suddenly develops, look for some stoppage in the fuel supply. First try the float needle, and if the petrol does not flow into the float-chamber, although there is plenty in the tank, there is undoubtedly a stoppage in the pipes or the filter, both of which should be thoroughly cleaned. Such stoppages are frequently caused by small particles of scale from the tank, pieces of waste or fluff, or by drops of water which will not pass through the filter or the jets. Many engines have a tendency to pop back when

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first started, from cold, but work satisfactorily after they have run a little time and become warm. The explanation of this has already been given in the paragraph dealing with hot-air supply.

Occasionally a float sticks, or is held up by grit, or the needle becomes bent or jammed, causing the carburettor to flood. Flooding may also result from a punctured float, in which case the petrol can be evaporated and driven off by immersing the float in hot water, and at the same time the issuing bubbles will show the position of the hole, which should then be soldered neatly, or, in the absence of solder, a temporary repair can be made by wiping a piece of soap over the hole.

A leaky joint in the inlet pipe may cause much trouble by weakening the mixture, and in an old engine leakage of air along the valve stems, due to wear in the guide, may have the same results. All joints should therefore be kept tight and leakages stopped as far as possible.

Very briefly, fuel-supply troubles and their remedies may be summed up as follows:

Engine pops back and stops: no petrol in tank, petrol pipe choked, filter stopped up, or water in petrol.

Engine pulls badly on hills: insufficient heating, or jet too small.

Engine flabby and exhaust offensive: jet too large, causing rich mixture.

No acceleration and engine staggers when throttle is opened: engine cold, or mixture too weak.

Carburettor floods: needle valve sticking, dirt under needle, valve or float punctured.

Consumption excessive: engine or transmission in bad condition, jet too large, ignition retarded, leakage of petrol, or brakes binding.

Let me here give a word of warning to drivers. A carburettor is a delicate piece of mechanism, but if properly fitted and treated carefully it rarely gets out of order. No driver should be misled by an engine knock to believe that there is something wrong with the carburettor, as under no circumstances can this be the case. Again, many drivers always blame the carburettor if an engine suddenly heats up, whereas the probable cause is that the fan belt is slipping, that there is no water, that the water-jacket is choked up, that more oil is needed in the crank-case, or because the ignition is retarded too much. Overheating is never caused by too much gas.

Lubrication.—Lubrication means the introduction of a separating film of oil or grease between two parts of a machine which have movement one upon the other. If the moving parts make actual

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Lubrication.—Lubrication means the introduction of a separating film of oil or grease between two parts of a machine which have movement one upon the other. If the moving parts make actual

metallic contact the surfaces will soon become roughened to such an extent that they may seize. The higher the speed of rubbing the sooner seizure will occur, and its consequence will be more serious.

Some parts of motor vehicles are designed so as to create friction, but such parts are few, and are for special purposes—such as the main clutch, the brakes, the fan belt and the tyres.

Of all the sources of friction in an engine, that of the piston against the cylinder wall is the largest item, and is double or treble the total friction of all the other parts of the engine put together.

Valve Troubles.—Valve trouble is usually indicated by a gradual falling off in power. On examination the valve faces will be found scored and pitted, and it is necessary to grind them down on to their seats to again produce a clean face. If the face is very deeply pitted, it may be necessary to clean it up in a lathe, after which it should be ground to a true bed on the seating. In an old engine the seatings themselves may become rough, and necessitate truing up with a special tool, or, if not too bad, an old valve can be used for this purpose with a slightly coarser grade of emery, finishing off with fine emery and the proper valve.

The operation of grinding is a perfectly simple one, but requires to be done with care. Only the very finest flour-of-emery powder, mixed with lubricating oil to form a thin paste, should be used. This should be spread evenly on the valve face, and under a slight pressure the valve turned first in one direction, then in the other, occasionally lifting it and turning it through about half a turn before letting it drop on the seat again. This is to prevent the emery getting into tracks. If a light spring is slipped under the valve head, and is long enough to lift the valve from its seat, it will be found a great convenience, as on relieving the grinding pressure the valve will be lifted and it can then be twisted as much as is necessary before pressing down again. The exhaust valves suffer most, due to the hot gases sweeping across their faces, and it is for that reason that one usually allows a little more clearance for the exhaust-valve tappets than for the inlet-valve tappets, so as to make quite sure that the valves really do close. When grinding in valves it is of course necessary to take care that none of the emery paste enters the cylinder or gets on the valve stem, and the valve, valve port and guides should be thoroughly cleaned before reassembling the parts, oiling the valve stems during the process. After regrinding valves it is usually necessary to re-adjust the tappet clearances, carefully tightening up the lock-nuts so that they cannot work slack. Each valve should be examined in turn to make certain that it is never held off its seat, nor has too much clearance—the clearance should never be less than $\frac{1}{64}$th of an inch, and never more than about $\frac{1}{32}$nd of an inch—but in order to get the quietest and best running it is advisable to adjust the

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tappets while the engine is still hot and the valve stems expanded to their maximum amount. It is not always easy to see if the clearance is right, especially if the head of the valve tappet is much bigger than the end of the valve; the tappet head may be a bit soft, and the end of the valve then punches a slight depression into it, so that the clearance is really more than it appears to be. It is, however, always preferable to have too much rather than too little clearance, as, although the engine will be noisy, there is less fear of burning out the valves.

If for any reason a camshaft has to be removed, careful search should be made for any marked teeth, and care exercised that the teeth of the timing gears are again correctly meshed when putting the camshaft back again. Occasionally, a valve sticks in the guide, due to insufficient lubrication, or it may be that the valve stem has warped. If a spot of oil on the stem is not sufficient to make it operate again the valve should be removed, and the stem rubbed down with a piece of emery cloth, or, if badly warped, carefully straightened in the jaws of a vice, after which it may be necessary to regrind the valve on to its seat. If the engine is provided with screwed valve caps the threads should be smeared with graphite and oil before replacing the caps, otherwise they may seize and be very difficult to remove. A driver should make quite sure that these are screwed up quite tight, and that there is no leakage. A simple test for leakage is to pour a little oil round the joint when the engine has been started, when any leakage will be at once apparent by the oil being blown away from the joint.

Cooling.—In small engines it is possible to rely on air-cooling, as on motor-cycles, but in larger engines a water-jacket is provided, and water circulated through this either by pump or natural circulation. In most cases it is usual to provide a fan to assist the cooling of the water as it passes through the radiator, and the fan belt should be kept at the proper tension, otherwise there will be slip.

Water-cooling troubles make themselves evident by steam being generated, but so long as steam is not blowing away, even if the radiator is uncomfortably hot to the hand, there is no danger, as an engine works best when the water is just below boiling-point. Like most complaints of engines, overheating may be of gradual growth, or it may develop suddenly. In the former case it means that the water-jackets and radiator have become coated with scale such as we find in a domestic kettle, except that the scale may also include rust and grease. Scale interferes with the passage of heat to a very great extent, but much of it may be removed by filling the jackets with a hot strong solution of common soda, then after leaving it to stand all night, drain it off, and thoroughly wash out with clean water. Soda must not be used if the radiator or pipes

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are made of aluminium, because soda is injurious to this metal. In such a case it is better to use Boilerine Tablets, or a solution of carbon tetrachloride.

If overheating shows up suddenly on an engine that has previously given no trouble, we must look for a broken or slack fan belt, a faulty pump, or leaking joint allowing water to escape, or the accidental opening of a drain tap. The most serious cause of overheating, however, is a cracked cylinder, as a very minute crack will allow gas to escape from the cylinder into the water-jackets, and the water will quickly boil. Some drivers appear to have difficulty in making tight joints in rubber connexions, but if a little rubber solution is smeared on the pipe it will not only act as a lubricant, but when it sets it will ensure a good joint.

Transmission Gear.—The transmission gear commences with the clutch and finishes at the road wheels. The two main portions of a clutch should disengage positively when the clutch is out, so that there is no dragging on the gearshafts. If the clutch becomes greasy it will slip, causing heating, and probably burning the lining, while if it is allowed to become fierce, it makes starting difficult, and throws undue load on the transmission system. A slipping clutch may be caused by insufficient spring pressure, the lining being badly worn, or worn so as to leave a ridge which prevents the cone entering any further, in which case the ridge can be removed with a chisel, sharp knife, or file. If none of the above causes is present, but the clutch still slips, a new lining should be fitted as soon as possible. Meanwhile, as a temporary expedient, thin strips of metal can be inserted underneath the lining between the rivets. A fierce clutch may be caused by too much spring pressure, or by the rivet heads standing proud of the lining, in which case the clutch will slip a little at first, and then take up suddenly. The remedy is to drive the rivets further in with a punch, so that they are below the surface of the lining. Another and frequent clutch trouble arises from the centre or spigot bearing becoming so worn as to allow the clutch cone to sag, and fall out of truth with the fly-wheel. This makes gear-changing a very difficult matter, because the clutch is never really free. If a clutch slips badly, the first thing to do is to wash the lining with petrol, and if the lining is of leather it should then be reconditioned by dressing it with castor oil or collan oil and leaving it to stand disengaged overnight, so as to allow the oil to soak in. If, however, the lining is of fabric, no oil should be put on it. As a temporary measure for a slipping clutch, it should be dusted over with fuller's earth, or, in the case of a fierce clutch, with powdered graphite, or french chalk.

Multiple-disc clutches are now frequently used, some of them being enclosed in an oil bath, whilst others are of the dry type. In

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the oil-bath type the case should occasionally be drained and washed out with paraffin and new thin mineral oil then put in. If thick oil is used it is liable to become sticky, and may cause slipping, whilst mixtures of engine oil and paraffin should never be used.

Between the clutch and gear-box many vehicles are provided with a small brake or clutch stop, the object of which is to bring the rotating parts of the gear-box to rest when the clutch is out, so as to make gear-changing easy. Attention should be paid to this small brake to see that it is neither too fierce nor too slippery.

The next link in the transmission is the change-speed gear-box. It should be supplied with the right quantity of suitable oil and occasionally drained, washed out with paraffin, and a supply of fresh oil then added. This cleansing and replenishing is necessary because, no matter how carefully used, fine particles of metal dust or chippings become separated from the gears, bearings, change-speed forks, etc., and if allowed to accumulate they cause extensive damage. The ideal lubricant is a good heavy mineral oil, but unfortunately some boxes will not retain it, and in such cases it is a common practice to mix oil and grease together; neither must be of the kind which produces a soapy mixture, because this implies the presence of acid, which will etch highly polished surfaces and cause damage. As a general rule the thinnest mixture of lubricant the box will retain should be used, not only because it flows freely to every part, but because it offers less resistance to the gears.

From the gear-box the drive is transmitted to the driving wheels through chains or a propeller shaft to the rear axle. If chains are used, it is useless to attempt to lubricate by pouring oil on to them. The only effective way is to remove the chains, wash them thoroughly in paraffin, drain them, and then soak them in a bath of hot grease and graphite, and again drain them. Any excess of grease should then be wiped off, or it will collect dust and grit. If chain-cases are provided they should be maintained in an oil-tight condition, and the oil kept up to the proper level. The chains should be kept at a proper tension—a little slack, but not slack enough to flog.

If universal joints are not properly lubricated, wear will take place, and backlash develop and damage all keys and gearing. The back-axle or differential case requires the same attention as is given to the gear-box. If pieces of metal are found on filtering the oil drained from casings, something is wrong, and the matter should be reported at once, or serious damage may follow.

Conclusion.—As a final word let me add that the best possible way of reducing the cost of maintenance of a tractor is by giving close attention to the matters which I have mentioned. If this is done, and the brakes and steering connexions are kept properly adjusted and all nuts and bolts kept tight, there is little to go wrong

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in a modern machine, apart from fair wear and tear, calling for the replacement of worn parts by new ones. If the care which I have advocated is not given regularly, abnormal wear and tear will take place, heavy costs for renewals will be incurred, and the value of the machine will rapidly depreciate. I would again urge owners of tractors to treat their machinery as they would treat their animals. If they do so, they will find themselves well repaid.

PRACTICAL EXPERIENCE OF POWER ON THE FARM

By E. PORTER, B.Sc., F.A.C.Glas.
Shifnal, Salop

I PROPOSE to deal in this paper with the application of power in my immediate district, and chiefly on my own farm of 330 acres, of which about 225 are under cultivation. The soil is a sandy loam, and with three exceptions the fields are fairly level. The farming in the district is based chiefly on corn, cattle and sheep; there are some farmers who produce milk, and some grow potatoes on part of the root break. My practice has been to depend chiefly on the live-stock department—on sheep, pigs and poultry—and on the arable land; to widen the range of crops by growing a considerable acreage of potatoes, carrots, parsnips, peas and green vegetables, in addition to corn and the usual roots. I have grown sugar-beet during the last three years. My farming, therefore, may be described as semi-intensive—organized, it may be added, as a business proposition.

The following figures, extracted from the annual reports of the Ministry of Agriculture, show a steady decline in the number of horses on farms in England and Wales:

Horse-Power

	Horses, Mares and Colts	*Acres of Arable Land*
1911-1915	1,165,000	11,131,000
1916-1920	1,134,000	11,805,000
1921-1925	1,064,000	11,144,000
1925	967,000	10,682,000
1926	927,000	10,548,000
1927	894,000	10,310,000

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The decline in numbers is evidently related to the shrinkage in the area of arable land, but the introduction of the commercial motor for industrial haulage has restricted very considerably the market for horses, resulting in a considerable fall in the number of foals bred on the farm. The Ministry, however, draws attention in the 1927 returns to the fact that the decline in breeding has been nearly stopped. Are we to conclude from this that horse-power in industry and on farms has been brought down under present conditions to the lowest point compatible with efficiency? It may be so; I am afraid, however, that I cannot give a satisfactory answer.

What are the chief reasons for the retention of horses on the farm? The reply is that horses are a handy and really effective source of power. They are the farmer's trusty friends in all weathers, and in all situations—on wet land, on sloping or hilly land, in chain work or shaft work, and are always able to give reliable service. They are slow, but they are very sure.

Cost of Horse per Working Year

	£	s.	d.
Food	25	4	0
Shoes, repairs to harness and sundry expenses .	6	5	0
Risk	4	0	0
Depreciation	4	0	0
	£39	9	0

I find, therefore, on my farm, where it is possible to work horses about 260 days in the year, that the cost per day is about 3s.

Cost of Ploughing per Acre

	Acres per Day	s.	d.
Two horses with one-furrow plough . .	$\frac{3}{4}$	18	0
Two horses with one-furrow plough . .	1	13	6
Three horses with two-furrow plough . .	$1\frac{1}{2}$	11	0
Three horses with two-furrow plough . .	2	8	6

By using a three-horse team and a double-furrow plough the cost of ploughing is brought down very considerably, and the same principle can be applied with economical results to other implements. One of the most recent improvements is the "Gower" two-horse root drill. It is adapted for sowing mangolds, sugar-beet, swedes, and similar seeds, over four rows at one operation, thus covering the ground at twice the speed of the ordinary mangold drill; a further gain being that the ridges are made at the time of sowing.

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Each ridge is made by two concave breasts converging from front to back, and the seed is deposited at the required depth immediately in front of the closing ridge. A special feature of the "Gower" drill is its capacity of working when the surface is wet after a shower.

Another valuable implement for ridge work is the pole ridger, carrying three bodies, which reduces the cost of ridging for potatoes by 50 per cent., and earthing-up by 66 per cent.

There is no reason to believe that the efficiency of horse-drawn implements will not be increased still further.

Engine Power on the Farm

Steam Tackle.—Steam ploughing and cultivating in this district are usually done by contract, the price per acre being 16s. to 18s. for ploughing, and 15s. to 16s. for cultivating twice, and 8s. per acre for harrowing twice. The farmer provides the necessary water and about 15 cwt. of coal per day.

The cost per acre is evidently not less than with horses, but there is of course the very decided advantage of rapid execution of the work.

The charge for mole draining is 9d. per chain, measured along the drain.

Tractors.—Tractors are now within the financial capacity of the average man, and it is probable that with the general-purpose tractor we shall see very considerable developments in the near future. At the present time farmers have not quite sufficient confidence in tractors; they know of too many now lying on the scrap-heap, and they know also of heavy bills for repairs, and of much valuable time lost in waiting for renewals of broken parts. Depreciation is a very heavy charge against the tractor. At their best, however, tractors are invaluable in times of pressure because of their speed and of their capacity for working continuously over long periods when it is necessary for arrears of work to be overtaken, or to make the most of periods of favourable weather.

During the last seven years I have used a Wallis tractor, which I have found comparatively easy to handle; it has sufficient speed and power, and is evidently economical of fuel. It is able to travel fairly well on loose ground, and, speaking not as an engineering expert, I have always considered that this power of easy travel is due to its light weight, to the width of its wheels, and its wedge-shaped gripping spuds.

The most suitable kinds of work for a tractor are, in my experience, the hauling of the two-furrow plough, the cultivator, and the self-binder; for belt-work it is excellent. In ploughing there is a certain loss of control over the plough itself—operated as it is from

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the front—and this lowers to some extent the efficiency of the work, especially on ground sloping sideways. I have not found harrowing and rolling very suitable work for the tractor because of the wheel-tracks, especially after crops have been sown, as subsequent harrowings fail to touch the young weeds growing along the tracks, and grass and clover seeds falling on these tracks are difficult to cover with sufficient soil. The hauling of the grass-mower has not been quite satisfactory; the wheels of the tractor travel along the edge of the swath, compressing the newly cut grass and rendering the work of the swath-turner more difficult. This defect could be improved by a more careful co-ordination of function between tractor, mower, swath-turner and horse-rake. A further difficulty has been the breaking of the cutting knives and several axles. A point in favour of horses is that they usually pull up when obstructions are met with, and the bill for repairs is correspondingly less than when tractors are used. Perhaps our implement makers will design a more suitable mower?

The hauling of the self-binder is perhaps the most suitable harvesting job for the tractor, as this is killing work for horses on hot days. My binder is a Massey Harris, and cuts a width of six feet. The speed attained is greater than with horses, and the knives cut smoothly in consequence. There have been no breakages due to the tractor which could not equally well be due to horses. There is a loss of cutting width when turning the corners, and it has been necessary for the man in attendance to cut them back with the scythe. There is a device, I believe, which enables the binder to cut the corners more completely, but I have not seen it in use. In difficult cutting, or in a crop of variable length, it is necessary to have a man or a boy on the binder itself; the driver of the tractor, however, being frequently able himself to manage the work of cutting after being well started.

The question of designing wider implements for tractor use in corn and grass harvesting has often been in my mind; but for English conditions and with crops which are often above the average it is difficult to see at the moment how these heavier crops could be handled economically by such implements. It would be a much simpler proposition with lighter crops, and in such cases wider implements could be operated with advantage.

The Tractor of the Future.—The improved tractor must, in my opinion, be of the general-purpose type—of light weight, of simple construction, easy to start, handy in the field and well protected from dust and grit, both inside the engine and about the bearings of the travelling wheels. The tractor must be powerful enough for the work, with low fuel and oil consumption, not too noisy when working, and backed by an efficient repair service.

The driver's comfort must be considered; a suitable platform

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and seat must be provided; the driving wheels must also be well guarded to keep the dust away from the driver in dry weather.

This improved tractor must be in the charge of a capable man, sufficiently skilled to keep the tractor running under reasonable conditions. When the tractor is in the shed it will be necessary to provide him with suitable alternative work, which will stand the higher rate of wages that must be paid him.

Cost of Working a Tractor.—The cost of ploughing with the tractor does not appear, in my experience, to be cheaper than with horses when the latter are pulling a two-furrow plough. I have not kept complete costings, but my driver has given me the following figures for fuel and oil consumption for a 21-acre field which, in comparison with the figures for other fields on the farm, seem to be typical: paraffin, 25 gallons; petrol, 5 gallons; lubricating oil, 4½ gallons, and about 1 lb. of grease.

Depreciation works out at about £45 per year, and, allowing 90 working days, the average figure is 10s. per day. As ploughing is heavier work than binding I propose to charge the ploughing at the rate of 12s. 6d. per day, and the lighter work at 7s. 6d. per day.

Repairs have averaged about £18 per year, which equals 4s. per day. I propose to charge 5s. per day against the ploughing.

Summary

	s.	d.
Fuel, oil, etc.	2	3
Depreciation (2½ acres per day)	5	0
Repairs	2	0
Wages (piece-work)	3	0
Cost per acre	12	3

If we assume that the charge for repairs is the same per day whether a larger or smaller area is ploughed, we can bring down the cost per acre from 12s. 3d. to 9s. 9d. by increasing the area ploughed from 2½ acres to 4 acres.

Harvesting.—The cost of cutting and tying the same field when in oats worked out at about 6s. per acre when calculated at the rate of 10 acres per day, and about 5s. 2d. per acre when 15 acres are cut per day, which is about the same cost as with horses.

Thrashing.—For belt-work I have found the tractor most satisfactory. As against the steam engine, the tractor depreciates more rapidly, and is not so useful in moving the thrashing-box. The drum appears to be operated as steadily with the tractor as with the steam engine, and in fuel consumption the tractor has a distinct advantage. About 5 gallons of paraffin and ¾ gallon of petrol appear to be sufficient for a day of eight hours, and with steam the

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Motor Cultivation.—I have often wondered why so little progress has been made with motor ploughs and cultivators, as it seems that control from the rear has distinct advantages. As a grower of roots on ridges of various sizes I have often seen the young growing plants damaged by the treading of horses. If one had a very light motor-cultivator which could travel between the rows, and operate tines, blades, discs, or other attachments, a great deal of damage could be avoided. Plants in the field may, of course, be destroyed in other ways than by horses, but it is important to realize that, in the case of sugar-beet, with roots having an average weight of 1 lb. (not very large roots), growing uniformly in rows of 18 in. and singled at 9 in. apart, the crop would weigh 17 tons per acre, which is about double the average yield, and indicates that considerable loss occurs in most cases.

Haulage of Farm Produce

I claim to be a lover of horses, but after being thrown headlong into the road on more than one occasion I was driven to the conclusion that it was safer to drive a motor-car than a horse along the surface of a modern road and I made the change-over, though with some reluctance at the time.

Now, I have also taken the farm horses off the road, and the haulage to station and market is done by hired motors.

My nearest station is four and a half miles away, and a local lorry owner has undertaken to haul manures, feeding-stuffs, and various kinds of produce in bags, at the rate of 4s. per ton, but it appears that a powerful competitor will shortly offer to do the same work at a lower rate. The usual load at the 4s.-per-ton rate is from 25 to 30 cwt., but occasionally 2 tons.

By using horses and moving a crop of potatoes at the rate of $7\frac{1}{2}$ tons in two days with one team, I estimate that the cost per ton would be about 3s. 9d. per ton—slightly lower than with the motor. Owing, however, to the greater speed and convenience of the motor, I prefer to keep the horses working on the land.

Sugar-beet is collected from the farm by the railway company's own lorries, unloaded at the station into railway trucks, and sent

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By using horses and moving a crop of potatoes at the rate of 7½ tons in two days with one team, I estimate that the cost per ton would be about 3s. 9d. per ton—slightly lower than with the motor. Owing, however, to the greater speed and convenience of the motor, I prefer to keep the horses working on the land.

Sugar-beet is collected from the farm by the railway company's own lorries, unloaded at the station into railway trucks, and sent

by rail to the factory at Kidderminster, at a cost of 3s. 10d. per ton for collection to the station, and 3s. 6d. per ton for railway freight, which makes 7s. 4d. per ton from farm to factory. For road haulage a contract price with a private firm was 7s. 6d. per ton from farm to factory. I have reason to believe that both these contract rates will be lower during the coming season. The beets have, of course, to be carted from the fields to a loading deck adjacent to the hard road, and assistance is given when loading the lorry at the deck.

Summarized haulage costs to Station—$4\frac{1}{2}$ miles distant

Horses ($2\frac{1}{2}$ ton loads)	3s. 9d. per ton
Light motor-lorry ($1\frac{1}{4}$-$1\frac{1}{2}$ ton loads)	4s. per ton
Heavy motor-lorry (6 ton loads)	3s. 10d. per ton

My chief market town is Wolverhampton, which is fourteen and a half miles away. The following figures represent the charges from the farm to the market and to various depôts in the town:

Potatoes in bags (2 ton loads)	8s. per ton
Potatoes in hampers (2 ton loads)	10s. per ton
Carrots, parsnips, peas and cabbages ($1\frac{1}{4}$ ton loads)	10s. per ton
Sheep and pigs (about 15 sheep)	15s. per load

An economy of some importance resides in the fact that these light lorries can take their loads of from 25 to 30 cwt. direct from the field, except when the ground is soft immediately after rain, when it is necessary to bring out the horse, and cart the load to firmer ground. Heavy motors must always remain on the hard road when being loaded.

The cost per ton when produce is sent to Wolverhampton by road to the station, and thence by rail, is about 15s., delivered to the market, which is, of course, quite an impossible figure.

Summing up, it will be seen that it is still difficult to reduce the cost of many kinds of field work to a point lower than is possible with horse-power, yet I am convinced that a general-purpose tractor, used in conjunction with horses, is a combination which under present conditions gives that variety of power which makes for high efficiency on our medium and large-sized arable farms. There are times when the value of the work done, say, during a spell of favourable weather, makes the actual cost of the job seem extraordinarily well worth while, and these are the times when the tractors give their best service, which may in some cases mean the difference between success and comparative failure.

For road haulage, horses are too slow, and are rapidly being

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Summarized haulage costs to Station—4½ miles distant

Horses (2½ ton loads)	3s. 9d. per ton
Light motor-lorry (1¼-1½ ton loads)	4s. per ton
Heavy motor-lorry (6 ton loads)	3s. 10d. per ton

My chief market town is Wolverhampton, which is fourteen and a half miles away. The following figures represent the charges from the farm to the market and to various depôts in the town:

Potatoes in bags (2 ton loads)	8s. per ton
Potatoes in hampers (2 ton loads)	10s. per ton
Carrots, parsnips, peas and cabbages (1¼ ton loads)	10s. per ton
Sheep and pigs (about 15 sheep)	15s. per load

An economy of some importance resides in the fact that these light lorries can take their loads of from 25 to 30 cwt. direct from the field, except when the ground is soft immediately after rain, when it is necessary to bring out the horse, and cart the load to firmer ground. Heavy motors must always remain on the hard road when being loaded.

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For road haulage, horses are too slow, and are rapidly being

superseded by motors. I feel, however, that it is better for most farmers to hire rather than to purchase a motor, as, in these days of telephones, there is no difficulty in bringing a motor to the farm almost at any time, which is a wonderful convenience.

In conclusion, it is obvious that mechanical power applied to agriculture is an important factor making for the improvement of farming conditions—a factor which may prove to have a very special appeal to the oncoming generation—and if in this way we can raise the standard of life on the countryside it will be due very largely to the skill and resource of our agricultural engineers. I hope that their efforts on behalf of agriculture may still further result in "better farming, better business, and better living."

ROTARY TILLAGE

By R. D. MOZER

Simar Rototillers

THE subject of "Rotary Tillage" is not a simple one and is not easily condensed, and I must confine myself to stating a few facts and deductions which may prove to be the basis for subsequent developments of this intricate matter. In certain phases of farm management the question is relatively simple—harvesters, automatic milking machines, and many other power-driven implements are manufactured along more or less standard lines, and often there remains only the problem to choose such machines as will give long life and continuous service.

In the department of tillage operations, however, the problem is more difficult. As a general rule, the farmer knows instinctively that such-and-such processes will yield certain results, but there is a wide gap between the process and the final result, and he is accordingly loth to change anything from his former methods, because he cannot foresee step by step what effect will follow the introduction of new methods at any stage of his operations. Hence the difficulties facing the agricultural engineer are very acute.

The first problem to be faced in connexion with the application of power to tillage operations is the nature of the power which should be used, but that is a problem which is beyond the scope of this paper. The second problem is whether the mechanical unit should be designed so as to make use of conventional tillage implements, or whether the implements themselves should be re-designed to fit in, as it were, with the usual consequences of the generation of power by mechanical means. Within the latter category we find

superseded by motors. I feel, however, that it is better for most farmers to hire rather than to purchase a motor, as, in these days of telephones, there is no difficulty in bringing a motor to the farm almost at any time, which is a wonderful convenience.

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only one class of implement, known in general terms as "Rotary Tillers."

There are, of course, considerable variations between the different rotary tillers, and in general there is a broad distinction to be drawn between those with rigid tools and those with elastic tools. All rotary tillers have for their object the production of a seed-bed in a single operation, and a machine capable of giving such a result without counteracting disadvantages must find its place wherever soil is to be tilled.

Mechanical power being essentially rotary in character, it is only logical to assume that such power should be employed in its original rotary form in connexion with the work of tillage. A simple illustration will suffice. In general, the axis of the rotary tilling unit is parallel to the main axle of the propelling wheels; it corresponds to the back axle of a car, and has a rolling action with the qualification that a certain breaking effect is caused by soil resistance and other factors. Most of us, however, as novices in the art of car driving, have forgotten to release at some time our hand brake and have only experienced a reduction of the maximum output of the engine, and by no means a complete extinction of power.

What probably constitutes the first recorded vision of rotary tillage as an accomplished art is to be found in the pages of Hoskyn's book *Talpa; or, The Chronicles of a Clay Farm*, written when steam-power was being adopted very largely in industry generally. Hoskyn foresaw an implement which, to use his own words, would be one "which completed the whole work of tillage as it moves along" and, "in one comprehensive act—and word—cultivation." Since the time of Hoskyn much has been said and done in the field of rotary tillage, yet it cannot be said that the results achieved, so far as a general adoption of a machine of Hoskyn's conception is concerned, are in accordance with the simple logic underlying the author's words. We need to examine in some detail the reasons why rotary tillage has not been adopted more widely than is actually the case, and it is unbelievable that this method will not be given at least the extensive trial which it deserves, so that the claims of its sponsors should at least be proved or disproved.

The introduction of mechanical power to the farm was in the form of tractors, and rotary tillers only made their appearance in this country after the War. Since the introduction of the latter machines a strong controversy has been carried on as to the respective merits of the two power units as compared one with the other, while each in turn is the subject of comparison with the horse.

Rotary tillers are generally specially designed, self-contained machines, and while modifications in design are usually possible to permit of the use of the power for such purposes as belt-work, etc., they do not at present replace horse-power to the same extent as do

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tractors. Nevertheless, it should not be impossible to effect modifications of design to rotary tillers to widen the field of usefulness of such machines to cover most farm operations.

It may be said that all the considerations which are leading to the replacement of horse-power by mechanical power in industry generally, apply, with a few modifications, to agriculture. The horse is an imperfect power generator because it consumes independently of the power supplied and whether required to generate power or not. Again, the horse consumes part of the products of the soil, and is in consequence an adverse economic unit, especially in the case of relatively small farms.

The tractor is uneconomical because, in order to get the necessary adherence, it must be given weight on the driving wheels or track. To drag a plough consuming effectively 4 h.p., a tractor weighing about 18 cwt. is wanted, which practice has shown to require an engine of at least 14 h.p., so that there is a waste of some 70 per cent. of the power generated.

This weight-cum-adherence problem is largely centred in the fact that the plough as used with the tractor exerts a backward draught. Similar considerations need not apply to rotary tillers, where the action of the revolving tines helps the whole machine forward. There is, consequently, a very much lower loss of power between the point of its generation and that of its application.

Nevertheless, rotary tillers so far produced—except the smaller types up to about 10 h.p.—have been wrongly evolved in not taking advantage of all the weight reduction which is possible. It must be admitted with some reluctance that there is at present no rotary tiller which is really fit for the farmer, and that only those more suitable for the nurserymen, etc., are at present sound commercial propositions.

The problem from the agricultural standpoint is a question of the respective merits of the plough and the implements which normally follow it, on the one hand, and the rotary tiller on the other hand. Here we are concerned only to find the best means to produce a tilth or seed-bed. On a properly managed farm the cost of seed-bed making represents about 10 per cent. of the crop value, and a 10 per cent. increase in yield as the result of better or more timely work would therefore cover this part of production costs.

Rotary tillage can effect much greater saving than this, as, for example, by eliminating several operations, by better utilization of manures—which are more uniformly distributed—and by a reduction in the amount of manure required.

The specific weight per horse-power of rotary tillers can be reduced to a minimum, and this reduction means that there is less compression of the soil. A distinction can also be made between the low compression of the soil and the low-friction effect of a set

tractors. Nevertheless, it should not be impossible to effect modifications of design to rotary tillers to widen the field of usefulness of such machines to cover most farm operations.

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of independently mounted tines, and the comparatively high friction between the plough and the solid earth which it is required to turn over in large masses.

The fact that the work of tillage is completed in one operation with the rotary tiller is an unquestionable advantage in spring cultivation, and, as seeding is the only operation subsequent to tilling, compression of the tilled soil is still further reduced. Again, the action of the rotary tiller is such that instead of the hard, smooth pan which is left by the plough, the bottom of the tilth is left rough, obviating the necessity to subsoil and permitting percolation of water during rainy periods, to be stored as a reserve for the top soil. Next, it is claimed that the tilth produced with the rotary tillers is a much more uniform and a finer one than can be secured by any other means, with the possible exception of very careful hand labour. The fine even texture of this tilth is productive of better aeration, while it is of considerable assistance in promoting free and rapid root growth.

The principal criticism against rotary tillage is its unsuitability for autumn cultivation. It is thought that because the tilth produced is such a fine one there will be a tendency, with heavy winter rains, for the soil to pan down and set hard. This is a point on which there is much conflicting evidence that must be carefully sifted before any general verdict can be passed. In any case it should be possible to modify the design of the tiller to enable a much coarser tilth to be obtained at will.

The question will be asked as to what evidence there is in practice that the claims for rotary tillage are justified. In the commercial field, rotary tillers are now comparatively well known amongst fruit-growers, market-gardeners and nurserymen, and have justified themselves to a much greater extent in connexion with intensive farming than with farming in its more general aspect. This is not surprising, since the principal objection to rotary tillage—namely, its probable unsuitability to autumn tillage—does not apply in this particular sphere. On the other hand, all the admitted advantages of rototillage apply. Market-gardeners require a fine seed-bed, ability to catch the weather, and facilities for sowing a fresh crop immediately the preceding one has been harvested.

As applied to the raising of root crops, very favourable reports are available, and one case is recorded of rotary-tilled soil yielding a potato crop of 30 tons to the acre. Very favourable results have also been secured with swedes, turnips, mangolds and sugar-beet. On the other hand, a conflicting experience was obtained at this Institute, where swedes were grown in three plots which had been respectively horse-ploughed, tractor-ploughed and rotary-tilled. The latter plot at first gave every promise of being the best crop of the three. Suddenly there occurred a marked change. The soil

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became "panned" or hard, the appearance of the foliage fell away considerably, and, in the final result, the crop was inferior in weight to that of the other two plots. My company has been invited to participate in further experiments at this Institute to ascertain whether this apparently deleterious effect of rotary-tilling can be overcome by the simple expedient of inter-cultivation at defined stages during growth. If, with one additional passage with the rotary tiller, with its tines set shallow to skim the surface, the pan can be quickly and effectively disturbed, there will be an answer to the somewhat widespread belief that the rotary tiller is unsuitable as an autumn cultivator.

Leaving once again this rather controversial field we can give a few moments' consideration to other points where the rotary tiller is of undoubted benefit. By a simple depth-regulation arrangement it is possible to use these machines, not only in the preparation of the soil for seeding, but for cultivation at all stages of growth. In the summer months they can be used to promote a fine surface mulch which is of such great benefit in helping to tide over the effects of scarcity of rainfall. They will deal efficiently with weed growths of variable natures, though it is to be noted that repeated cultivation is the *modus operandi* for destroying these pests effectively, for, unless frequent cultivation is resorted to, a marked increase in weed growths is noted, which is incidentally a finger-post pointing to the possibilities of rotary tillage as a fertilizing method.

Reviewing the field covered by this new method it may be stated that rotary tillage is an accomplished fact in certain departments. It exists as a fully evolved commercial force in such work as nurseries and for specialized crops, and it is extremely useful in its present form for certain farming operations requiring intensification of methods. The larger types of existing rotary tillers represent by no means the last word, and we may say that, so far as general farming is concerned, rotary tillage is still in its infancy. It is doubtful if there is one agriculturist who is not sufficiently far-seeing to watch with interest the developments in the practice which are bound to take place during the next few years, and, to quote Hoskyn once more: "In the Arts as well as in morals, difficulties are opportunities."

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ELECTRIC PLOUGHING AND TRANSPORT

By R. BORLASE MATTHEWS,
Wh.Ex., A.M.I.C.E., M.I.E.E., F.R.Ae.S.
Greater Felcourt, East Grinstead

Part I.—*Electric Ploughing*

Ploughing is one of the most important and heaviest of farm tasks and also the most expensive item on the arable farmer's bill. Opposition to mechanical power for ploughing is often met with in agricultural circles. It is claimed that the introduction of power-driven cultivating machinery, instead of reducing costs, would of necessity increase them, as the keep of the horses would be the same and the mechanical power would only be carrying out the work that the horses would otherwise be doing. There is, however, one fallacy in this argument, for the work of ploughing cannot be extended over a long period and horses can be used for this purpose only during slack periods. For land to be well cultivated the ploughing must be completed as early as possible in the autumn; and again, it often occurs in this country that long wet periods are experienced which delay work on the land, but, when a favourable opportunity presents itself, the farmer who has something quicker than the horse to carry out the work is in a very advantageous position. Further, the modern electric plough can now be adapted for all forms of field work—such as harrowing, rolling, harvesting, etc.

Another argument commonly used is that English fields are too small for this kind of work. This argument, however, is made on the assumption that all electric ploughs are very large sets, capable of covering an enormous area in one day. There are, however, the round-about and tractor types of ploughs, which are quite suitable for small fields—there are many in use to-day in vineyards in the South of France; these vineyards, it must be admitted, are a more difficult proposition than the smallest of fields. A great deal of the author's work has been in the direction of solving the problem of the ideal type of ploughing equipment for the small farmer of individualistic ideas.

It is doubtful whether the operation of ploughing, as at present practised, is really an essential part of tillage, and in this respect it is interesting to note the rapid progress made by the rotary cultivator during the past few years; these machines lend themselves extremely well to an electric drive. The flexible cable passes from

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It is doubtful whether the operation of ploughing, as at present practised, is really an essential part of tillage, and in this respect it is interesting to note the rapid progress made by the rotary cultivator during the past few years; these machines lend themselves extremely well to an electric drive. The flexible cable passes from

a small mast on the machine through a pulley at the top of a pole fixed at the side of a field, it then hangs in a loop, the end of the loop passing to the mains being fixed to the top of the pole. In the loop there is a pulley carrying a weight, so that the cable is automatically paid out or drawn back at a constant tension, thus preventing it from being accidentally run over.

The 10 h.p. size can deal with an area of from 0·2 to 0·5 of an acre per hour, at a depth of from 4 to 10 in., travelling at a normal speed of $1\frac{1}{2}$ miles per hour.

The 30 h.p. size can deal with an area of 0·5 to 1·5 acres per hour, working to a depth of 14 in.

There are a number of different systems of electric ploughing in operation to-day, though they practically all fall into one of two classes—viz. tractors or rope haulages. The capacity of the larger ploughs is enormous, many ploughing up to 30 acres in one day.

These sets are equipped with either 80, 100, 125 or 150 h.p., 5000 volt, three-phase, slip-ring induction motors, many of which are capable of a momentary overload of 60 per cent. The general design is based on British steam-plough experience, hence only the electrical features are really new. The main disadvantage of this equipment is the very great weight of the haulage sets, which is sometimes as much as 14 tons for each winder, thus large headlands are required. Many ploughs of this type are to be seen in France and Germany, and also in Russia. The method of operation is essentially the same as with the familiar steam-ploughing tackle. Two portable electric-motor haulages are placed, one at each side of the field, each haulage having a steel-rope drum, driven by counter-shafting through the electric motor. The average speed of the steel cable is about 1·66 yards per second, though it is possible to reduce the speed to 1·1 yards per second. With this equipment it is claimed it is possible to plough 30 acres per day, with a furrow depth of $9\frac{1}{2}$ to 12 in. The power consumption per acre on heavy clay soil of average moisture content is about 15 units (kw.h.), while the speed of ploughing is $3\frac{1}{3}$ miles per hour.

The majority of double-rope system haulages are similar in design, though many are equipped with auxiliary petrol engines of about 50 h.p. to enable the haulage to move from field to field and from farm to farm, while in others the familiar anchor-wagon device is used.

Continental manufacturers have realized that more attention must be paid to the need of the individual farmer, and have designed sets with this purpose in view.

The Estrade equipment has a number of novel features. The haulage cable passes through a pulley at the end of a pivot arm, whose movement is assisted by a series of oil dashpots. The resultant of the pull and the weight of the haulage always passes

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The 10 h.p. size can deal with an area of from 0·2 to 0·5 of an acre per hour, at a depth of from 4 to 10 in., travelling at a normal speed of 1½ miles per hour.

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through the line joining the points of contact of the soil and the two inside wheels. These wheels are fitted with flanges, which, with the rims, enclose a prism of earth. In this way great stability is obtained, for, instead of depending on the friction of the iron arms on the earth surface, the much greater friction of this compressed prism of earth on that lying beneath is utilized. The manufacturers claim that this type of haulage gear can provide a pull of three times the weight of the set.

In another new machine, ramps, or inclined runners, are provided upon each haulage set, and when the plough reaches the end of its journey it mounts up on the haulage set, ready for transfer into position for the next set of furrows. Thus, headlands are reduced to a minimum and manœuvring is greatly facilitated.

Electric Tractor Ploughs.—One of the main problems is the method of dealing with the flexible cable connecting the tractor to the supply point. The best principle evolved so far is to mount the feed cable-reel on the tractor itself. In this way the cable is paid out and laid to rest on the soil instead of being dragged after the tractor, while on the return journey it is picked up and wound on to the drum. Various devices are used to ensure that the cable-reel winds and unwinds at the correct speed.

In Italy the ingenious method of attaching the cable to a small balloon (lifting power about 100 lb.), and thus raising it out of the way, has been employed.

Electric tractors fitted with a tramcar-type collecting trolley or bowl, picking up the current from a bare overhead conductor, have not proved satisfactory on account of the trouble in designing supports so as to maintain sufficient tension on the conductor and at the same time facilitate progressive movement at the end of each furrow.

Tractor ploughs are generally fitted with electric motors of from 20 to 30 h.p., and when equipped with three-share ploughs will plough, on an average, 6 acres per day to a depth of 8 in., the current consumption being about 28 units (kw.h.) per acre.

On the author's farm a 12 h.p. modified roundabout electric plough is employed.

The author considers that the double-winder rope system, with petrol engine for field transport, is the most satisfactory for large contractors working over large areas. The *ideal* plough for the farm of 200 acres and upwards has yet to make its appearance. The author suggests that it should be designed with a half-creeper track. The flexible cable should be raised above the ground, with automatic winding and an automatic-feeder cable, similar in design to that employed on the M'Dowall plough. A storage battery should be provided for moving the equipment from field to field, and when not in use on the land or within reach of overhead lines.

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The main motor should be of about 25 h.p., while an additional winding motor of about 2 h.p., with an automatic hysteresis control, should be incorporated for operating the cable-drum. A mast should be fitted on the tractor to support the cable so that it hangs free in the air for a distance of about 30 to 40 yards. A plough should be mounted at both ends of the tractor so as to obviate the necessity of turning at the end of each set of furrows. A tractor of this type would plough from 40 to 60 acres from a single contact in the middle of the field. This tractor could also be used for such work as cultivating, harrowing, harvesting, rolling, seed-drilling, etc.

While it is not possible to give exact figures as to the cost of electric-ploughing, since so much depends upon special circumstances in each area, yet the author has calculated the cost of operating some of the machines from figures given by manufacturers and users. On the double-rope system with two haulages, the cost works out at 5s. 7½d. per acre, while the figure for electric tractors is 5s. 1d. per acre. These figures do not, of course, include overhead expenses, but include depreciation, interest, cost of cable, repairs, labour, and electric power at 1d. per unit, the depth of ploughing being from 6 to 8 in. When allowance is made for overhead charges these figures still compare favourably with the contract prices quoted for all other forms of ploughing. Another way of dealing with the cost is to mention that the consumption of electric current for ploughing varies from 15 to 22 units (kw.h.) per acre—a comparatively small sum at 1d. per unit, the usual charge.

There is, of course, still room for improvement in the design of electric ploughs, but it is rather refinement and evolution that is needed, coupled, of course, with the provision of an adequate distribution system to supply the large amount of electric power required.

For the supply of electricity to rural areas the usual type of overhead, three-phase transmission line will no doubt be used, and the only special feature introduced for field work is the method of connecting the high-tension lines to the portable transformer wagon. For temporary tappings it is often done by means of special hooks, having insulated handles and cable connected to the transformer cabin, though a better way is by means of permanent "fool-proof" pole contacts, of which special types already exist for pressures up to 10,000 volts. These are very easily operated from the ground by a long rod, and remove any possibility of wear and damage to the main transmission line.

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farmer, and chief among these will be comparatively simple transport equipment which will both expedite and facilitate the work on the farm, thereby reducing the amount of labour employed per unit of work performed.

Handling Crops.—A large proportion of the cost of hay and corn is accounted for by the high labour costs involved in handling the material both in the field and the buildings. A useful method of unloading the crops at the barns is to utilize specially prepared slings or automatic grab forks, in conjunction with an obvious system of ropes or nets, placed in the wagon before loading. The whole operation of unloading can then be performed by one man.

The method most frequently employed on farms on the Continent for hoisting these loads is a modified form of the Temperley transporter system, operated by an electrically driven hoisting gear provided with two hoisting drums and sets of brakes. The gear is conveniently located near the unloading point, thus giving complete control to the men in charge. When the load is hoisted to the top of the barn the pulleys jam, and the load can be traversed in either direction. The whole arrangement is of a very cheap and simple design, and can be operated by a 3-5 h.p. motor.

Transport equipment can also be used profitably at thrashing time—for instance, electrically driven chain-conveyers should be employed to transport the sheaves from the rick or barns to the thrashing-machine, with an automatic device incorporated on the thrashing-machine for cutting the bands on the sheaves and separating each sheaf before delivering it on to the drum. The thrashing-machine could then be permanently mounted on foundations about 4 ft. above floor-level. The installation of a permanent thrashing-machine would make it possible to deal with straw in the following ways: the straw could be (1) baled on leaving the thrasher, (2) passed through a sheaf binder, (3) blown to a straw-yard through a tube, or (4) transported by an inclined elevator. With methods 1, 2 and 4 the straw should be delivered on to a horizontal conveyor, so that at convenient intervals trap-doors can be placed in the run-way, which permit of the delivery of the straw at any desired point. When method 3 is adopted the delivery tube can be as long as 200 yards. It is usual to make up the length with 10 ft. lengths of light galvanized piping. At the end of the last tube an arrestor is fitted so as to collect the straw neatly at the desired point. For driving the grain a distance of 50 yards a 5 h.p. motor-driven fan is required, while an 8 h.p. motor-driven fan will double the distance, and a 10 h.p. size will carry it 200 yards. Where fans of efficient design are used, and attention is paid to the form of ejecting device, even smaller motors can be employed. The capital cost of these conveyors is not high, as they are of very simple design.

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worm-conveyers, delivering it on a horizontal or inclined belt-type conveyor direct to the granary.

With mechanical assistance of this nature one or two men only are needed at the thrasher, while other two pitch the sheaves on to the conveyor.

Central Manuring Plants.—A system of manuring market-gardens by means of stand pipes in the orchards has been carried out for quite a number of years on many Continental farms, especially those in Switzerland. The stand pipes are connected to a manure tank adjoining the main cow byres by means of underground pipes. The urine from the cowsheds flows directly into the tank, and when the plant is about to be used, old rotted manure is thrown into the tank and water added, and the whole contents agitated by means of revolving arms or by circulation through centrifugal pumps.

The question of the supply of electric current for transport purposes and for electro-mechanical appliances for work in the field and in the farm-buildings is relatively simple, if farming is carried on on modern lines, since the power demand would be so great that electricity-supply undertakings would be anxious to cultivate the rural load and would therefore be only too pleased to provide the necessary distribution system.

Recently the writer, in conjunction with Dr A. Ekstroem (the well-known Swedish authority on rural electrification), has prepared a scheme for completely electrifying the whole of Lincolnshire—which is typically an agricultural county. If the scheme can be carried through, rates as low as ½d. per unit will be offered for purposes where the current is used for long periods—such as thermal storage, electric cookers and water heaters. It is hoped to bring a supply of electricity to over 75 per cent. of the inhabitants of the county within six years. In each of the above-mentioned areas a number of typical farms will be completely electrified (including electric ploughs) in the reasonable manner that the farmers would do themselves if they had had many years of experience of the use of electricity, and also knew what farmers in other countries were doing.

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THE DISCUSSION

Sir Merrick Burrell, in opening the proceedings, said that the purpose of these meetings was to bring together farmers, representatives of industries connected with agriculture, and agricultural scientists for the discussion of specific problems in agriculture. The present Conference was the sixth of the series, which had already dealt with lucerne, fodder crops, sugar-beet, green manuring, and the art of cultivation.

The subject chosen—"Power for Cultivation and Haulage on the Farm"—was beyond question of wide importance at the present time: how far could mechanical power aid the farmer, what form of power was best, and to what extent would it aid, or replace, traditional horse-power operations? His personal opinion was that the horse would continue to hold its own, although mechanical power would prove a very useful aid. He thought that the bulk of the discussion would centre around the tractor, but he asked the audience not to forget the long and honourable record of steam-power, and the claims of electric-power, in which large developments might come in the near future.

Mr W. C. Dampier-Whetham, in opening the discussion, said that his own experience was mainly on grass-land farms. Horses were cheap to buy, depreciation was small, a team could be split and distributed to different pieces of work—and they were better for small fields. The small development in power in agriculture as compared with other industries is due to the following reasons: (1) industries were localized in factories, whereas agriculture had a diffuse and spasmodic requirement; (2) the farmer's main source of power was the sun, whose energy was utilized by the growing crops, and all other forms of power were subsidiary to this. The development of electric-power was held up in England by the high cost of overhead lines, due to stringent safety requirements. They cost £500 per mile against £200 on the Continent. The amount of power needed per acre was small, but over the whole rural area the load would be economic.

Mr H. Deck (Ransome, Sims & Jefferies) considered that the use of electricity for barn machinery was its most likely outlet. For cultivation and haulage work permanent and movable cables and heavy batteries would be highly inconvenient He thought there would be little immediate change, except in the direction of more economical design, either in the tractor or the implements designed for use with it. Nevertheless there were great possibilities

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in deeper ploughing and cultivating. He stressed the importance of speed in all farming operations in our uncertain climate.

Mr Bosanquet of Alnwick (delegate of the Northumberland N.F.U. to the Conference) said that as a practical farmer he supported all that Mr Porter had said. He farmed 1800 acres of light hilly land, mostly reclaimed from moorland within the last one hundred and fifty years. At first tractors were unsatisfactory because buried boulders broke the tackle, but they were excellent for thrashing. He used motors exclusively for haulage, except for carrying rations to the farm-buildings and transporting women workers between the fields and their homes each day, for which light horsed carts were used. This practice has been found so advantageous to the farm work, and is so much appreciated by the workers, that the horse will shortly be replaced by a light motor-lorry, which would also be used for ordinary transport.

Mr J. R. Bond (County Organizer for Derby) thought that the imported-meat trade was largely responsible for the present depression in agriculture, and believed that laying down land to grass could not help. The present difficulties largely arose because of our traditional practice of keeping animals partly to supply manure.

Steam cultivation was too costly. There had been little improvement in engine design since 1850. The engine need not be heavy, and in any case the distribution of weight over the present form did not correspond with the point at which the pull was experienced. Very little had been said about the destruction and killing of weeds during cultivation operations. It seemed as if half of a farmer's life was spent in getting a tilth, whereas it was his experience that more than half of a farmer's life was spent in destroying weeds. He thought that if an efficient machine for this purpose could be devised the time of cultivation work could be greatly reduced.

Mr Black (President, Suffolk N.F.U.) stated that his experience was gained on heavy land in Suffolk, where he could not work his horses for 260 days a year as Mr Porter did. He found the tractor essential to get through the necessary work in time. On large farms it was better to have both heavy and light tractors and lorries rather than general-purpose types. He supported conveyor distribution for produce in the granary.

Mr Van Dijk (Messrs MacLaren's engineer for export trade) said he had come over from the Continent especially for this Conference. On sugar and tobacco soils in Sumatra, where the

in deeper ploughing and cultivating. He stressed the importance of speed in all farming operations in our uncertain climate.

Mr Bosanquet of Alnwick (delegate of the Northumberland N.F.U. to the Conference) said that as a practical farmer he supported all that Mr Porter had said. He farmed 1800 acres of light hilly land, mostly reclaimed from moorland within the last one hundred and fifty years. At first tractors were unsatisfactory because buried boulders broke the tackle, but they were excellent for thrashing. He used motors exclusively for haulage, except for carrying rations to the farm-buildings and transporting women workers between the fields and their homes each day, for which light horsed carts were used. This practice has been found so advantageous to the farm work, and is so much appreciated by the workers, that the horse will shortly be replaced by a light motor-lorry, which would also be used for ordinary transport.

Mr J. R. Bond (County Organizer for Derby) thought that the imported-meat trade was largely responsible for the present depression in agriculture, and believed that laying down land to grass could not help. The present difficulties largely arose because of our traditional practice of keeping animals partly to supply manure.

Steam cultivation was too costly. There had been little improvement in engine design since 1850. The engine need not be heavy, and in any case the distribution of weight over the present form did not correspond with the point at which the pull was experienced. Very little had been said about the destruction and killing of weeds during cultivation operations. It seemed as if half of a farmer's life was spent in getting a tilth, whereas it was his experience that more than half of a farmer's life was spent in destroying weeds. He thought that if an efficient machine for this purpose could be devised the time of cultivation work could be greatly reduced.

Mr Black (President, Suffolk N.F.U.) stated that his experience was gained on heavy land in Suffolk, where he could not work his horses for 260 days a year as Mr Porter did. He found the tractor essential to get through the necessary work in time. On large farms it was better to have both heavy and light tractors and lorries rather than general-purpose types. He supported conveyor distribution for produce in the granary.

Mr Van Dijk (Messrs MacLaren's engineer for export trade) said he had come over from the Continent especially for this Conference. On sugar and tobacco soils in Sumatra, where the

soil resistance was very high, he had, after ten years' work, reduced the plough draught by 50 per cent. Had he had the advantage of the Rothamsted studies on soil resistance he could have solved the problem much earlier. The vital question to-day was to reduce tractor costs. This implied a reduction in the number of moving parts in the engine, and the use of crude oil—the Diesel engine was the solution. It was now in use successfully for cable tackle, and smaller tractor types were also in use.

Mr HUGH YOUNG dealt with his experience as a farmer on hilly land at High Wycombe. He stressed the necessity in tractor design for keeping the weight as near the ground as possible and well distributed over a large base. The front wheels of one of his tractors tended to be pulled off the ground when travelling uphill, while another, when working across the hill, tended to topple over sideways.

The purchase between the tractor wheel and the land was the weakest point in present-day design; a four-wheel drive or track-laying type would be better: his three-wheel drive tractor hauled a binder last summer on land so greasy that the two-wheel drive tractor could not manœuvre itself with no load at all behind it.

He strongly urged the desirability of an efficient two-furrow one-way plough for the tractor: no horse plough was needed to open and close the furrows between the lands; no time was spent in driving along the headland between lands, which, for an acre with 200-yard furrows, meant some 380 yards extra travel; the passages over the same piece of headland were three against eighteen with the fixed plough. He invariably used one-way ploughs with horses, and was surprised at the little use made of them in England (except in the anti-balance form in the south-west counties), in view of their great popularity on the Continent. Finally, in his hilly land the tractor was worth its cost for binder work alone.

Major C. E. BENTALL (Heybridge Works, Maldon) raised the question of the performance of implements rigidly attached to the tractor. If the essential feature of such an implement was that the wheel of the tractor took the place of the land wheel, it would result in uneven work on uneven land. This seemed an argument against a simple rigid attachment between tractor and implement. With the existing types, the hitch was flexible, thus allowing the plough to follow the contour of the land and maintain an even depth of furrow.

He drew attention to the value of the tractor for broadsharing. This implement was formerly very popular, and did undeniably

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valuable work, particularly in stubble cleaning, but its use had been largely discontinued, mainly for the reason that it was considered to overtax horses.

Mr F. H. Johnson (Bull Motors, Ipswich) considered that electric power would be economically used for cultivation only if a single engine were used, the implement being pulled backwards and forwards between this and an adjustable anchor truck, by means of a double haulage rope. This method would halve the number of permanent supply cables needed on the farm and would eliminate the necessity for any flexible conductor winding and unwinding with the movement of the implement—an arrangement that is cumbrous at the best.

Although the above scheme is the most practicable so far as distribution is concerned—which is the governing factor—there is the great disadvantage that the electric tractor and anchor truck must of necessity be hauled to their work by internal-combustion or steam tractors, and the only way that this can be eliminated is to fit the electric tractor itself with an engine, or heavy and expensive batteries, which will enable it to travel by road when disconnected from the distributing wires. The latter introduces complications which would be highly unsatisfactory in the hands of ordinary agricultural labour, and would certainly be very difficult and expensive to install and operate where the supply is alternating current, as it would be in almost every case of rural electrification. For the larger ploughing equipments the question of petrol-electric operation is well worth consideration, as by this method the control of the tackle could be simplified enormously. The whole equipment could be handled by means of a simple drum-type controller, similar to that used on tramcars. The capital cost of the tackle compared with steam gear would be reduced, and the depreciation would also be less. There would be a considerable saving in labour, since no supplies of boiler-feed water and coal would be needed. The petrol-electric system could be made perfectly reliable; the reliability of the electrical portions is at least equal to that of the petrol engine, and, with properly designed machinery, the depreciation on the electrical portion is almost negligible. One advantage of the petrol-electric system is that it would give a very wide range of hauling speeds. It could very easily be so arranged that the maximum tractive effort for which the equipment is designed was developed at any speed from standstill to the normal full speed, corresponding to the maximum output of the engine driving the dynamo. The same plant could also be made capable of developing half the maximum tractive effort for which it was designed, at a speed as high as twice the normal hauling speed if necessary. This would enable a great variety of work to be handled, and on the

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lighter work would enable a great economy in time to be effected, provided the maximum speed available could be utilized effectively.

Therefore, by utilizing the electrical drive, an equipment could be provided which has a very wide range of hauling powers and speeds, and able to utilize the various implements which it is designed to haul, to their full capacity. Provided the electrical engineer is shown what is required, there is no reason why he should not produce plant which will deal in a highly efficient manner with a large variety of haulage and other problems.

Lieut.-Col. F. Garrett, C.B.E. (Leiston Works): To get more men on the land and to pay the higher wages necessary we must introduce, as far as climatic conditions allow, mechanical means into agriculture, and thus increase the output per man. My firm has recently developed a device for reducing the labour of haulage on soft or wet land. The idea applies to all vehicles (even tractors) and enables, for instance, one horse to haul a load off heavy land that formerly taxed two.

I disagree entirely with Mr Bond on the development of steam-power; it has advanced quite as much, by higher pressures, superheaters, valve-gears and turbine systems, as any other form of power. In haulage, ten-, six- and four-ton load steam vehicles are popular, and beat the internal-combustion engine in cost of running, durability and capacity for overloading and overspeeding; steam-power has still many useful outlets in agriculture.

The two grave obstacles confronting electric-power in agriculture are the absence of cheap and light batteries, and the high capital cost of current distribution systems.

Mr B. G. Shorten (J. & F. Howard, Ltd., Bedford): Steam cultivation on large estates has been successfully proved for many years. The smaller landowners and tenant farmers in many cases employ the service of a contractor owning steam tackle. In this way extensive areas have been kept under cultivation which otherwise would have been found most difficult to deal with.

As agricultural engineers, we deplore the present tendency of so much land being laid down in grass. The time is not far distant when landowners and farmers will find it to their advantage to devote more attention to this question of tillage. The figures plainly show that the importation of foreign meat will increase rather than decrease, and with this undoubted position in view, how can farmers hope to make grass-land pay by producing beef in competition with such an array of foreign competitors?

I do not agree with the suggestion that manufacturers have adhered to the principles of the horse-drawn implements in designing tractor implements. I can assure you this is not so. Most efficient

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self-lifting arrangements are now fitted, operated by the driver. It has been suggested that more efficiency could be secured by combining the tractor and, say, two-furrow plough, in one unit, braced together with certain flexible movement. On closer experience problems will be found presenting difficulties—*e.g.* a double-furrow plough closely connected to tractor, negotiating uneven surfaces, is deprived of the necessary vertical and horizontal movements required for dealing with rough and heavy soils, and so far more satisfactory results are produced by independent couplings.

While we believe the demand for tractors is steadily growing, and their usefulness more recognized, it must not be taken as indicating that horse-power is on the verge of collapse. The implement production of my firm is about 85 per cent. horse-drawn as against 15 per cent. tractor-drawn. I believe horse-power will continue to be largely used, more especially by the medium and smaller farmers, and, by reason of the variety of duties performed by them, they will remain first favourites with the majority of farmers. I believe the horse, the tractor and the steam tackle, with their suitable implements, hold an important place in the development of our farming industry, and where well and wisely employed, even under existing conditions, all three can be used with progressive and profitable results.

Mr Harold Drewitt gave some figures for the cost of tractor work on his farm near Chichester. His tractor was bought shortly after the War and was very extravagant in paraffin and oil. His second purchase was made about five and a half years ago, and this tractor, in its working life of three years, ploughed 1615 acres (taking 5 acres of cultivating as equivalent to 1 acre of ploughing); the average cost of operations per acre was:

	s.	*d.*
Labour, fuel and oil	9	6
Repairs	4	2
Depreciation	4	9
Total	18	5

His third purchase was made two and a half years ago, and has, up to the present time, ploughed the equivalent of 1640 acres at a cost per acre of:

	s.	*d.*
Labour	2	5
Fuel and Oil	4	4
Repairs	1	9
Depreciation	2	6
Total	11	0

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These figures do not include belt and miscellaneous work, which was not sufficient materially to affect them.

The driver, who has driven all three tractors, is an excellent ploughman but not a mechanic—all except the simplest repairs have to be done by a skilled mechanic; during the life of the present tractor there has been only one stoppage due to mechanical breakdown. The most expensive part of breakdowns is not the cost of repair but the delay to the work of cultivation.

When there is great pressure of work in the summer, two drivers work the tractor 18 hours a day, thereby doubling the daily output of work.

Mr G. R. Hunter (Midland Agricultural College) thought that interchangeable wheels or tyres for the tractor were of great importance. A figure of 90 days per year seemed to be the average working time of the tractor on the land, and even this was not reached in wet seasons. Some simply attached system of rubber-tyred rims for road work, and a suitable trailer, would be very useful as a means of increasing the yearly working time, and especially advantageous to those farmers whose holdings were some distance from a railway station or market. It would reduce, or perhaps obviate, the necessity for a motor-lorry; a non-governed tractor, fitted with brakes to comply with regulations, would, however, be needed.

He thought that the horse had well held its own in the discussion, and suggested that not enough stress had been laid on the great advantages of higher speed and power that the tractor afforded. On the College farm this year they had, thanks to tractors, been able to cross every stubble twice; few Midland farmers were in that fortunate position.

While he agreed that certain tractor implements, being adapted from horse-drawn types, did not adequately utilize the power of the tractor, the modern disc-harrow should be excluded. Properly set, it taxed the tractor to its utmost and did better work than the horse implement.

Mr T. Milburn (Principal, Midland Agricultural College): The relative value of horse and tractor work was a matter of expediency rather than of cost. Just as the best horse-ploughing could not equal spade-work, so tractor-ploughing could not equal the best horse-ploughing; nevertheless, poor tractor-ploughing done at the right time may give better results than good horse-ploughing done too late in the season. To discuss their relative merits only on a cost-per-acre basis was beside the point.

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often obtained when there was a period between the respective operations to allow the ground to dry, weeds to be killed, and weed seeds to germinate. The same objective applied to rotary tillage.

Mr H. Currant (Farm Foreman, Rothamsted) spoke of his experience with the Austin tractor on the Rothamsted farm.

It was valuable for the autumn ploughing of clean stubbles, and in harrowing down before the drill, when the ploughed land was dry enough. The tractor was most useful in the cultivations for spring crops and roots. The land could be re-ploughed and tilled quickly, and the extra depth of cultivation needed for roots could be easily obtained without upsetting the horse work. Further, the tractor could deal with any field needing bare fallowing, and plough and cultivate it as many times as it might require. One could not plough fallow land too much in the summer when the land is dry.

For neatness of ploughing on clover, ley or stubble the single-furrow horse-plough beats the tractor, because it is the same plough following round its own work, and it is "held" by the ploughman; the tractor-plough, being pulled along and guided only by the tractor, cannot be expected to turn out work of the same quality.

Rolling the corn with the tractor is not an ideal job; a big acreage can be covered in a day, but the wheel-marks show below the roller and much of the corn on the headland gets over-rolled. But it will deal really well with a rough piece of uncropped land in the spring or summer; working in the low gear it will take a heavy set of harrows fastened behind the roller if desired. The tractor was unsuitable for drilling, ridging or bouting some of the lighter harrowing, rolling and, if he might use the term, "horse-hoeing": neither could one divide up the horse-power of the engine and use it for so many carts in times like haytime and harvest.

In conclusion he invited the tractor-plough makers to fit a more efficient skim coulter, as one of the chief difficulties in tractor-ploughing was to bury the rubbish. He also urged tractor manufacturers to fit some plugs that will not persist in oiling up, and to provide a more comfortable seat for the driver.

Mr G. A. Barber (Messrs. J. & H. McLaren, Ltd., Leeds): The various papers read to-day emphasize the need for greater economy on the farm. As a means to this end I would advise the more extensive use of machinery. The most up-to-date implements and power units, embodying simplicity and low running costs, must be employed. The use of machinery requiring highly skilled labour is neither advisable nor necessary for farm work to-day. A large proportion of the agricultural machinery produced in this country at the present time is sent to foreign countries where only native

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labour is available for operation. Mechanical cultivation may be divided into two systems—namely, the Cable system and the Direct system. In the Cable system the steam engine is being replaced by the motor-windlass, in which Diesel Oil Engines are used as the prime mover. This has reduced the working costs tremendously, and, in addition, provided a power unit weighing 7 tons as against 14 to 17 tons in the case of the Steam Cable Engines. Such a tackle can be worked in the field practically all the year round, and its light weight greatly facilitates its movement from field to field. The Diesel engine has the flexibility of the steam engine, and such complications as magnetos and carburettors—the two parts requiring special care and attention—are eliminated. The fuel costs for ploughing 500 acres, double cultivating 500 acres, also harrowing and rolling 1000 acres, amount only to £75 on medium to heavy soil, the depth of work ranging from 6 in. to 12 in. A variety of implements can be worked with this system, and a series of change-gears permit the implement to be operated at the desired speed, in accordance with the views expressed by Dr Keen.

In the direct traction system, too, the steam engine has been superseded by the internal-combustion engine, the very latest developments being the introduction of the Diesel Engine Direct Tractor. The fuel costs per acre with this tractor are under 1s. when working in average soil—a great advance in economy when compared with the petrol tractor. Simplicity here, again, is the keynote, and as the whole of the mechanism is enclosed—a point stressed by Mr Burford—a long life is assured.

The work I have seen carried out with rotary tillers both in this country and abroad does not lead me to believe that this class of implement will be extensively adopted in this country.

Mr J. E. Newman (Institute of Agricultural Engineering, Oxford): The objections raised by the ordinary farmer to the tractors are usually—(1) difficulty of maintenance, and (2) padding the ground. With regard to maintenance, the most modern tractors have reached a high degree of reliability and with ordinary care should give little trouble.. Much of the trouble experienced in the past has been due to faulty design, and even now there is room for improvement. Farm tractors, under working conditions on many farms, cannot be garaged every night without serious loss of working time, and tractor designers should recognize the fact.

A good deal has been said about the non-mechanical nature of the ordinary farm hand, but there is no reason why agriculturists should include a lower proportion of mechanically minded folk than the rest of the community.

The farm of to-day, apart from tractors, has a lot of machinery. Consider the binder—one of the most complicated bits of machinery

labour is available for operation. Mechanical cultivation may be divided into two systems—namely, the Cable system and the Direct system. In the Cable system the steam engine is being replaced by the motor-windlass, in which Diesel Oil Engines are used as the prime mover. This has reduced the working costs tremendously, and, in addition, provided a power unit weighing 7 tons as against 14 to 17 tons in the case of the Steam Cable Engines. Such a tackle can be worked in the field practically all the year round, and its light weight greatly facilitates its movement from field to field. The Diesel engine has the flexibility of the steam engine, and such complications as magnetos and carburettors—the two parts requiring special care and attention—are eliminated. The fuel costs for ploughing 500 acres, double cultivating 500 acres, also harrowing and rolling 1000 acres, amount only to £75 on medium to heavy soil, the depth of work ranging from 6 in. to 12 in. A variety of implements can be worked with this system, and a series of change-gears permit the implement to be operated at the desired speed, in accordance with the views expressed by Dr Keen.

In the direct traction system, too, the steam engine has been superseded by the internal-combustion engine, the very latest developments being the introduction of the Diesel Engine Direct Tractor. The fuel costs per acre with this tractor are under 1s. when working in average soil—a great advance in economy when compared with the petrol tractor. Simplicity here, again, is the keynote, and as the whole of the mechanism is enclosed—a point stressed by Mr Burford—a long life is assured.

The work I have seen carried out with rotary tillers both in this country and abroad does not lead me to believe that this class of implement will be extensively adopted in this country.

Mr J. E. Newman (Institute of Agricultural Engineering, Oxford): The objections raised by the ordinary farmer to the tractors are usually—(1) difficulty of maintenance, and (2) padding the ground. With regard to maintenance, the most modern tractors have reached a high degree of reliability and with ordinary care should give little trouble.. Much of the trouble experienced in the past has been due to faulty design, and even now there is room for improvement. Farm tractors, under working conditions on many farms, cannot be garaged every night without serious loss of working time, and tractor designers should recognize the fact.

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The farm of to-day, apart from tractors, has a lot of machinery. Consider the binder—one of the most complicated bits of machinery

there is. On the mechanical farm of the future, men with a mechanical bent will be as necessary as those with a love and eye for animals on a present-day stock-raising farm.

These objections to the use of tractors apart, the gravest objection most farmers have to it is that it will pad the ground. Our climate and the nature of our soil make this objection a real one, though the ill-effects are often exaggerated. Padding, or compression of the soil, is caused more by the tractive force of the machine than by its dead weight, and it is bound up with the shape of the lugs or strakes and the size of the wheels. Caterpillar tracks have the great defect of heavy cost and of excessive wear. It seems doubtful if these are not inherent in the design, and it is possible that some form of skeleton wheel will be the eventual solution of the difficulty. The Institute of Agricultural Engineering has had the Dawe Wave Wheel under observation for some time, on tractors of varying weights. When these wheels are fitted to a light tractor—such as a Fordson—the wheel-tracks can be harrowed out, and they have the great advantage that when the tractor is being used for general haulage on the farm it can move off soft ground on to a hard farm road, or go through a muddy gateway without slipping.

If further experience bears out our present opinion, they, or some development of the principle, will greatly increase the all-round utility of the tractor. It is this which needs to be increased; the number of hours which many tractors work is far too small, and it is chiefly by increasing the number of jobs which the tractor does that this can be altered. Of course, not only are our implements designed for the horse, but to a large extent farming practice is based on the use of the horses as its main source of power.

Now that a more economical source of the power is available, some of our practices might be altered with advantage. Such alterations will, however, come gradually, as the result of experience. I might mention as an example of greater experience and confidence, that tractors are now used in the hay-field to pull hay loaders. This is now common, but six years ago was hardly heard of. The tractor does this job better than horses, it pulls more steadily, particularly with a big load, and the wheels straddle the window, whereas horses walk on it.

I agree with Mr Bond about steam cultivation. The great weight of the present sets is at the bottom of most of the objections to their use: and that weight is not necessary to prevent slipping. Witness the ability of the M'Laren Diesel Motor Cable sets to work, and their success. At the same time the cable system has probably had its day in this country, and no improvements can be expected to sensibly increase its sphere of usefulness.

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As Mr BLACK said, it is unlikely that one type of general-purpose tractor can do all the work of all farms. Possibly the evolution of the tractor will be in two ways, one being in the direction of a stronger machine capable of easily ploughing three or four furrows in strong land, and used for cultivation work proper and the heavier belt-work—as thrashing—the other being in the direction of a light machine, capable of doing the work of a four-horse team and used for harvesting and drilling and the lighter work generally. Such machines are being evolved, and are necessary if horses are ever to be replaced to any considerable extent by tractors.

Mr J. W. COLLIS (Tractor Traders, Ltd.): Cost data, while of very great value, is most difficult to compile to apply to all conditions. In making comparisons as between horse and tractor work I do not think sufficient stress is laid on the many jobs the general-purpose tractor can do. I submit that with the "caterpillar" or track-laying type of tractor there is hardly any work on the farm it is not capable of doing.

On the question of electrical power, it is significant that in countries where it is so easily obtainable from natural sources—*e.g.* the "Niagara Peninsula"—it has not been applied to farm work on a far-reaching scale.

Hardly enough stress was laid on the necessity of more draw-bar horse-power in the tractor and the advantage of securing deeper tillage so essential for the cultivation of sugar-beet and other root crops. Direct traction is much cheaper than steam tackle by stationary engines, but the necessary power must be available at the draw-bar without track slippage to do the work. I agree with Mr Deck that to take advantage of the speed and superior draw-bar horse-power of the better type of tractor, and to produce a satisfactory implement to use with it, requires the closest possible co-operation on the part of the tractor manufacturer, the agricultural-implement manufacturer and the agricultural expert.

Captain E. H. GREGORY (Rothamsted) pointed out that no comparison was made between roads necessary for lorry work and horse work.

Both the farm wagon and cart are capable of standing the strain of bad roads, and at the same time carrying heavy loads. The lock of the wheels of the modern farm wagon allows it to turn in its own length. The horse is able to get on to other ground leaving the weight of the wagon on the road. An attempt to turn a lorry on a very wet day in a small track will, without doubt, lead to the bogging of the lorry directly it gets on to soft ground. Again, the condition of these tracks is generally so bad that the continued use of a heavily laden lorry on them would not only

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make them worse, but would most decidedly shorten the life of the lorry. Lorries in use on such tracks are either of the 7 cwt. or the 1 ton type, and even these have difficulty in negotiating the roads in bad weather.

The question of repairing the roads so that they may be fit for use with motor traffic is one which would involve a great deal of money. In many cases the farmer is bound by his lease to keep his roads in repair. A few cart loads of stones are put down at most irregular intervals in order to fill up the holes, for as long as a farm cart drawn by a horse can proceed along the road, it is in a state of good repair. The main roads throughout the country are gradually being altered in order to stand the extra heavy wear they receive on account of the increase in lorry traffic. It therefore follows that, if this increase is to spread to the farm, the same change, even if on a smaller scale, will have to take place on rural roads, and the question is, who is going to pay for it?

Mr J. M. BANNERMAN (Agricultural Economics Research Institute, Oxford) stated he had undertaken, under the auspices of his Institute, an examination of the economy of power on the farm, and the resultant effect on the efficiency and standard of living of the farm labourer. The economic evidence put forward, while representing adequately individual examples of actual fact, only serves to draw attention to the necessity of a much wider survey. Issues of deeper significance are also involved. For example, stress is laid in these times on the trend of the efficient agricultural labourer towards the town, and it is one of the crucial questions whether or not this efflux of the best rural worker could be stemmed in proportionate degree to the introduction of machinery. The ideal of obtaining an approximation of rural to urban conditions, both of work and standard of living, is a strong justification for Mr Matthews' advocacy of electrical power on the farm. The recent Electricity Bill should make the availability of this form of power more universally possible.

All the factors that contribute to the efficiency and contentment of the rural worker are of far-reaching importance, and discussions concerning improvements, mechanical and otherwise, on the farm would, I think, be ultimately of greater use were the social and economic point of view kept well to the fore.

Sir JOHN RUSSELL, in summarizing the discussion, said that four main points arose: (1) The need of elasticity in the source of power: in this direction horses were superior; (2) The necessity for getting the utmost out of the source of power: at present horses still retain an advantage here because of the traditional love of the farmer for them, which showed itself in the attention given

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to keep the horses fit; but this was a decreasing advantage because with the coming of the bicycle, and later the motor-cycle, into rural life, a mechanical turn of mind was growing up in the country-side; (3) The close adaptation of the implement to the source of power: here, again, the advantage of the horse was declining and improvements in power-drawn implements were constantly being made; this work necessitated the co-operation of the implement manufacturer, the engine manufacturer and the soil investigator; (4) The necessity for keeping up the speed of work so as to be well ahead in all operations: here the tractor was definitely superior, especially as it could do the extra emergency work, which was beyond the capacity of horses.

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GENERAL SUMMARY OF PAPERS AND DISCUSSION

By B. A. KEEN, D.Sc., F.Inst.P.

(1) Six forms of power are in use, to varying degrees, on the present-day farm: horses, and engines whose motive power is (*a*) steam, (*b*) gas, (*c*) petrol or paraffin, (*d*) low-grade fuel, (*e*) electricity.

(2) None of the mechanical forms of power is likely to replace the horse in the near future. The horse is very adaptable; a team can be split up and distributed to different kinds of work. The main functions of mechanical power are to provide a reserve of power for heavy and urgent work in cultivations and harvest, and to release horses for haulage work. The general characteristics of each form of power are discussed in the following paragraphs.

(3) *Steam.*—This is the most flexible form of power. Increased load does not "stall" the engine, but merely reduces its speed. It has long been established for deep and rapid ploughings and cultivations, in the familiar cable outfits. The work is done almost entirely by contract, few farmers having enough large areas to justify owning a set. Some difference of opinion exists as to whether the heavy weight of the engines is really necessary; and haulage of water and coal to the engines, and the time spent in getting up steam, are regarded by the farmer as disadvantageous. The development of steam wagons for general road haulage has not yet spread to agriculture.

(4) *Gas.*—Its use is confined to stationary engines, for driving barn machinery, etc. Very few gas engines are in use, and their number is decreasing.

(5) *Petrol or Paraffin.*—Engines of this type constitute by far the greatest number in use on the farm, and their number is constantly increasing, both in the form of stationary engines and tractors. Modern designs are much more economical of fuel and oil than those introduced just after the War, and stoppages due to mechanical defects have been largely overcome. Stationary engines are used for barn machinery, although the tractor is commonly employed for the heavier belt-work, in addition to its use in hauling binders and cultivation implements. Its use for road haulage has hardly begun as yet.

(6) *Low-grade Fuel.*—Heavy oils and low-grade fuel can be successfully utilized in the Diesel type of engine with the double reduction of fuel costs and depreciation, because of the simpler

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form of engine, fewer moving parts, and lower temperature of ignition. The use of Diesel-type engines for cable-tackle sets is now an accomplished fact, and a successful form of light tractor also is said to be in use.

(7) *Electricity.*—The electric motor is by far the simplest form of prime mover. There are only the two main bearings and the brush-holders requiring occasional attention, and no mechanical aptitude on the part of the worker is necessary. The necessity for a cable that has to be wound and unwound as the implement passes across the field is a drawback for cultivation work, and a grave difficulty is the necessity for a storage battery or petrol engine for independent motive power.

(8) It appears that steam-power will continue in use for heavy cultivation work, but may be seriously challenged by the Diesel engine; on the other hand, the steam wagon may be developed for haulage of farm produce to market. The paraffin or petrol tractor will for some time be the most general form of farm power for belt-work, cultivations, harvest operations, and perhaps road haulage. Electric-power can increase only with a spread of electrification of the rural areas, and the heavy cost of overhead lines, due to stringent safety precautions, is a serious obstacle. Calculations indicate that the total rural load would be economic, while electric light in the homes and in the farm-buildings would add to the comfort of the workers, and improve their efficiency. The petrol-electric system, that aims at combining the advantages of electric drive with the independence from fixed cables of the petrol engine, appears worthy of serious attention.

(9) There is general agreement on the design and specification of the general-purpose tractor—*i.e.* the machine for the average farm, where one only, or at the most two, would be employed. It should be of the light type, weight about 30 cwt., centre of gravity near centre of wheel-base and as low as possible; 22-30 h.p.; revolutions not exceeding 1200 per minute; strong and efficient radiator; gear drive fan and water pump; governed engine; magneto ignition; forced lubrication; strongly designed crank-case; accessibility to all parts needing adjustments; dust-proof ball or roller bearings; gears machine-cut and heat-treated, and of the highest grade material; rear axle of strong design, and front axle sprung and pivoted; two forward speeds and reverse, and efficient brakes on rear wheels for road haulage; fitted with oil filter and air clarifier; adjustable draw-bar, pulley for belt-work, and independent power take-off for direct coupling to machinery; speed and power to drive full-size thrashing machine; facilities for rapid conversion of wheels from farm work to road haulage, and *vice versa*; protection for driver from dust, etc., and a comfortable seat.

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general-purpose machine is not so suitable as two separate types: one a heavy tractor for three- or four-furrow ploughing, and the second of lighter design for cultivating, belt-work, etc.

(11) The general-purpose tractor is used for about 300-700 hours yearly, as against 1700 hours or more for the horse. The average cost is about 3s. per hour of work; the corresponding figure for the horse is 5¼d. This comparison does not take into account the extra speed and power of the tractor, enabling it to do more work per hour. On a cost-per-acre basis, where these factors are included, the tractor is cheaper than horses for ploughing, but dearer for all other forms of cultivation.

(12) Where the tractor is given a full load, therefore, its cost of operation compares very favourably with horse-power. The present forms of tractor implements—with the possible exception of ploughs—do not give the tractor a full load, and the practice of hauling implements in tandem—*e.g.* two binders, or harrows following cultivators—is not always possible, and certainly not convenient, with present designs.

(13) At present the tractor finds its chief outlet in ploughing after harvest, spring ploughing and cultivations, haulage of binders and driving of thrashers. It is of the utmost value, especially in times of pressure, and even if the cost of operation were much higher than it actually is, it would amply repay this by its ability to get work done at critical times.

(14) The design of tractor-drawn implements, with few exceptions, has not kept pace with the development of the tractor. This is perhaps the chief factor limiting its more extended use on the farm.

(15) There are suggestions from practical men that the tractor plough should be improved: a two-furrow one-way type is advocated, linked on to the rear of the tractor and not hooked on to the drawbar. The linkage would have to be such that a reasonably constant ploughing depth was maintained on uneven land. The ordinary skim-coulter also is said to be unsatisfactory. The disc harrow is said to be very suitable for tractor work. The killing of weeds is a most important object in cultivation operations, and if implements were designed with this aim more specifically in view it is possible that the actual number of operations now considered necessary to produce a tilth could be reduced.

(16) The use of combined tools, of the rotary cultivator type, is now well established for light market-garden soils. For ordinary agriculture they are still in the experimental stage. Since the aim of this machine is to produce seed-bed in one operation, the problems of soil tilth are of special importance. The use of a light machine that, with suitable attachments, could hoe and cultivate between the rows of root crops is a possible development of considerable promise.

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(15) There are suggestions from practical men that the tractor plough should be improved: a two-furrow one-way type is advocated, linked on to the rear of the tractor and not hooked on to the drawbar. The linkage would have to be such that a reasonably constant ploughing depth was maintained on uneven land. The ordinary skim-coulter also is said to be unsatisfactory. The disc harrow is said to be very suitable for tractor work. The killing of weeds is a most important object in cultivation operations, and if implements were designed with this aim more specifically in view it is possible that the actual number of operations now considered necessary to produce a tilth could be reduced.

(16) The use of combined tools, of the rotary cultivator type, is now well established for light market-garden soils. For ordinary agriculture they are still in the experimental stage. Since the aim of this machine is to produce seed-bed in one operation, the problems of soil tilth are of special importance. The use of a light machine that, with suitable attachments, could hoe and cultivate between the rows of root crops is a possible development of considerable promise.

(17) The use of the tractor for road haulage of farm produce is, apart from the general question of suitable rural roads, dependent upon (*a*) some simple and rapid attachment for conversion of land wheels to road wheels, or *vice versa*; (*b*) increased speed. Since rubber-shod wheels are practically standard equipment for road vehicles, and since, for land work, a proper grip is essential to prevent slipping and loss of effort, it appears that both rubber blocks, and strakes or spuds, must be provided, in a readily interchangeable form. Although there are some promising designs, they are still in the experimental stage. The track-laying or caterpillar track has not yet found extended favour in this country; neither has the four-wheel drive. The latter is worthy of fresh attention from designers.

Increased speed of work would be of great use for cultivations as well as road haulage. It has been shown that, as far as the soil resistance alone is concerned, the extra draw-bar pull needed increases much more slowly than the speed of work. Although, in addition to this, there would be increased power needed to propel the tractor itself at the higher speed, it appears that the limit of compromise between speed and durability has not yet been reached.

(18) The traditional policy of laying down land to grass in periods of agricultural depression may need revision, in view of the great developments in the imported-meat trade. One alternative would be an intensification, in suitable areas, of arable farming in which special attention would be devoted to vegetable products of a semi-market-garden type, whose culture would call for the extended use of power farming methods.

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HORSE AND MECHANICAL POWER IN FARM OPERATIONS

By B. A. KEEN, D.Sc., F.Inst.P.
Assistant-Director Rothamsted Experimental Station

The advent of mechanical power on the farm began in the middle of last century, when steam-power was first applied to cultivation. The agricultural Press of that period—particularly the *Journal of the Royal Agricultural Society*—bears much evidence of the high hopes entertained for this innovation. The enthusiasm was not without reason, for everything pointed to a long period of abounding prosperity in agriculture; in fact, the decade 1852-1862 has since been known as "the golden age of English farming." It was succeeded only too soon by the great depression that began in the late 'seventies, and it is significant that steam cultivation weathered this period of stern trial, and still remains to-day an established practice. But its struggle for survival clearly showed that its true position was an adjunct to, and not a substitute for, horse labour. Steam-power came to stay as a valuable aid in rapidly breaking heavy land in the autumn, and for deep spring cultivation—especially for crops like potatoes, that respond to a deep tilth.

In more recent years the internal-combustion engine has rapidly extended into agriculture, and the situation that arose when steam-power was introduced has emerged again, only in an intensified form. In the first place, the petrol or oil engine is a lighter unit than steam tackle; it is thus more comparable to the horse for ordinary farm work, and its cost permits the average farmer to purchase it, whereas he must put his steam work out to contract, with the risk that it will not be done at the most convenient time. In the second place, the internal-combustion engine has revolutionized road transport and haulage methods, and may do the same for farm haulage.

The latest information shows that the use of power for all purposes is steadily, or rather rapidly, increasing on the farm, in spite of the great depression of the past years: the extent can be seen from Table I., taken from *The Agricultural Output of England and Wales*, 1925, published in 1927 (Cmd. 2815. H.M. Stationery Office).

TABLE I

NUMBER OF AGRICULTURAL ENGINES RETURNED AS USED IN:

	1908	1913	1925
(a) *Fixed or portable*—			
Steam	8,690	7,719	3,731
Gas	921	1,287	1,125
Oil or petrol	6,911	16,284	56,744
Electric	146	262	700
(b) *Motor tractors*—			
Field work	...	...	14,565
Belt work (only)	...	...	2,116

The returns were voluntary; it is estimated by the Ministry of Agriculture that these represent about 75 per cent. of the engines in use. The increase in petrol engines is very great, and is far more than the decrease in other forms. Again, there were too few tractors to be recorded in 1913; in 1925 there were more than 16,500. It is evident that the internal-combustion engine has come to stay in agriculture, and our task in this Conference is to discuss to what extent it seems likely to replace horses, and to outline, on the basis of our present experience and information, those directions in which further improvements are needed.

The subject is twofold; it involves both technical and financial considerations, and, although they are so closely interwoven in practice, it is better for discussion to separate them as far as possible, and to take the financial side first. We have much information in our own farm records at Rothamsted, that Mr Garner has kindly summarized for me, and various departments of agricultural economics in the country have willingly given me additional data from their own detailed costings investigations.[1] The figures are in general agreement, and may be taken as reasonably close estimates of the costs of tractor and horse operations on the typical mixed farms where the arable area is not less than 40 per cent. of the whole, and is usually more.

Before considering the costs of different operations—*e.g.* ploughing and cultivating (with either the horse or the tractor)—it is desirable and instructive to see the general average cost for all work with each form of power. We will take horse-power first. In theory

[1] My thanks are due to Messrs King (Edinburgh), Thomas (Reading), Venn (Cambridge), and Wyllie (Wye), for help and information.

this is simply obtained; it is only necessary to obtain the total yearly cost of food, depreciation, shoeing, veterinary service, etc., less a credit for manure produced, and to divide this by the total number of hours that the horses worked, to arrive at the cost of a horse-hour. In practice the estimation of this figure is not so simple, as there are many interlocking costs, the fair apportionment of which is difficult, if not impossible. For this reason the practices of economists engaged in agricultural costings vary. In some cases "stable labour" is not charged; in others, depreciation and repair of implements is not included, and so on. The figures in Table II. have been obtained from several sources, and modified to bring them as far as possible to a common basis. They are the averages for a small number of farms in each case.

TABLE II

COST PER HORSE-HOUR IN PENCE, EXCLUDING IMPLEMENT DEPRECIATION AND REPAIRS

Year	*Rothamsted*	*S.E. England*	*Eastern Counties*
1923-1924 .	7·75[1]	5·11	4·62
1924-1925 .	...	5·33	5·08
1925-1926 .	6·75	5·56	4·94
1926-1927 .	...	...	5·95

These figures refer to widely different soil types and cropping systems, but are sufficiently close together to make the average of some significance. The somewhat high figure for our own farm is explained by the presence of several hundred experimental plots. Although the accounts for these are kept separate from the normal farm operations, they have to be worked by substantially the same staff and farm equipment. This arrangement is both inevitable and costly, not only for the experimental plots but the rest of the farm, and it is surprising that the figure is not much higher.

The original figures for the Eastern Counties included implement repairs and depreciation, and as the cost of this was not given separately, the round sum of 3d. per horse-hour was deducted to give the values in Table II.; our own figure was 3·44d., and seemed rather too high.

It appears, therefore, that a fair average cost per one horse-hour is about 5¼d. This figure includes cost of food, less credit for manure produced, cost of shoeing, veterinary service and medicine,

[1] Includes much hired horse labour, which is notoriously expensive.

harness repairs and depreciation, attendance, depreciation on the horses; it does not include implement repairs and depreciation, certain overhead charges on buildings and managing expenses, and of course the man's wages are excluded except that portion coming in under attendance charges.

The next step is to obtain a similar figure for the tractor, and this is more uncertain, as few costings have yet been made. In Table III. are some collected results.

TABLE III

COST PER TRACTOR-HOUR, EXCLUDING IMPLEMENT DEPRECIATION AND REPAIRS

Year	*Rothamsted*		*S.E. England*	
	s.	*d.*	*s.*	*d.*
1922-1923	3	$6\frac{1}{2}$	...	
1923-1924	5	5	3	2
1924-1925	3	3	2	8
1925-1926	3	3	3	1
1926-1927	3	3	...	

These figures include tractor depreciation, fuel and oil, repairs, and a few sundries, but do not include implement depreciation and repairs and driver's wages, except in the Rothamsted figures, where the commissions paid to the farm-hand acting as tractor-driver are included, and amount to just 10 per cent. of the total cost per tractor-hour.

A figure of 3s. per tractor-hour is probably not far away from the average cost, although in the figures from which Table III. was constructed there were, just as in Table II., very wide variations in cost from farm to farm.

However, on a reasonably equal basis of comparison, we may say, with fair accuracy, that a horse-hour costs $5\frac{1}{4}$d. and a tractor-hour, 3s., —or nearly seven times as much—and to this must be added the difference between the hourly rates of wages for horsemen and tractor-drivers.

This comparison is based on the total work of all kinds that the horse and the tractor perform on the farm, and too much weight must not be placed on it. It has been arrived at by a drastic process of averaging, and it includes not only widely different types of work but different systems of agriculture, and varying degrees of skill in management. Still, as a general over-all figure, it gives some precision to the comparison of the two forms of power.

The next information desirable is the relative costs of tractor and horse for the same kind of work. A certain number of comparisons for work on the same farm are available. These are collected in Table IV. on a basis of costs per acre, and include also some tractor figures for which horse-figure comparisons are not available.

TABLE IV.

COST PER ACRE FOR HORSE AND TRACTOR, INCLUDING WAGES

	Rothamsted	*South East*	*East*	*South West*
Ploughing—				
Horse . .	20/-	19/10, 14/10, 17/2	...	...
Tractor . .	15/9	14/6, 11/11, 8/-	13/7	(18/5), 11/-
Cultivating—				
Horse . .	2/6	4/	...	...
Tractor . .	3/6	4/5	3/6	...
Harrowing—				
Horse . .	1/6			
Tractor . .	3/6			
Rolling—		...	2/7	...
Horse . .	1/6			
Tractor . .	2/1			
Harvest—				
Horse . .	2/7	2/8, 2/1	...	...
Tractor . .	3/11	3/6, 4/7¼	4/3½	...

Here again, although there are appreciable variations, the general run of the figures is sufficiently close for our purpose, and we may now proceed to discuss the bearing of these costings figures on the technical and practical questions.

The first question that arises is an obvious one: Is the tractor likely to replace the horse as the main source of power in British agriculture? At first sight it appears equally obvious that the answer is a definite negative, since from Tables II. and III. we have seen that a tractor-hour is seven times more costly than a horse-hour. But the question is not so simple: the cost per hour is decreased if the number of hours worked is increased. At present the tractor on the average farm is used for 300 to 700 hours per year, while the horse puts in at least 1700; so there is ample opportunity for reducing the cost of a tractor-hour, if the practical

problems of using the machine on the farm to a greatly increased extent can be solved. In addition to this there is the certainty that the present-day running costs of a tractor will be reduced by improvements in design and by better care of the machinery. The distribution of the charges over the various items shows that, at present, fuel and oil account for about 50 per cent. and repairs and depreciation for 50 per cent. Beyond remarking that this indicates the responsibility for improvement, which lies equally on the manufacturer and the user, we shall not discuss it further, as other papers will deal with both these matters in detail. However, the improvement already achieved is shown by the two figures for S.W. England in Table IV. These were obtained on the same farm. The higher cost (in brackets) refers to a tractor working during 1922-1925, and the lower cost to a present-day model.

The second question that arises is: Assuming that the tractor is to be used mainly as an addition to horse labour, in what direction can it best help? Table IV. gives important information: the costs per acre in ploughing are appreciably cheaper with the tractor than with horses. In all other operations the tractor is dearer, but it need not necessarily be so. Ploughing is cheaper because the tractor is working at or near its maximum capacity, while in the other operations its load is too light. Until some mechanical genius builds an extensible tractor on the "unit" principle we must aim at increasing the load. The farmer can do this to some extent with his existing implements. Two binders can be hauled in tandem, harrows can be hitched behind cultivators—if the condition of the ground permits—and so on. But these are makeshift arrangements, for the setting of the front implement has often to be altered because of the drag behind it, and a wider headland also is needed for turning. There is scope here for the implement maker.

Up to this point we have based the comparison of horse and tractor work entirely on costs of operations. But the great advantage of the tractor is its power and speed, and its ability to work for long periods. It enables rush periods to be dealt with so that the work can be kept well ahead. The results are reflected in the final yield and the financial returns, but it is almost impossible to manipulate the figures to show the part played by the tractor. Unfortunately, in our climatic conditions the farmer knows only too well the results of a short enforced delay at a critical period, and has no doubts whatever about the advantage of being well ahead with his work.

This aspect can best be seen by taking a few typical examples:

(a) *Autumn Cultivation in Dry Weather.*—The important operation of stubble-breaking in these conditions often necessitates adding extra horses to the team, thus slowing up the harvest and carting. The tractor easily deals with the work.

(b) *Autumn Cultivation in Wet Weather.*—On heavy land in a wet autumn speed is essential if the work is to be done before winter sets in. The tractor can work the binder at high speed and for long hours, setting free horses for carting and cultivations.

(c) *Spring Cultivation.*—After a wet winter, and in a rainy spring, the intervals between a sodden state of the soil and a condition too dry for proper working are very short, and considerable areas have eventually to be pulled down into a "forced" tilth. The tractor can cope with the rush of work, thus increasing the area of land in good tilth.

Many other instances could no doubt be mentioned, and, when it is remembered that these advantages are also given by a machine that on heavy work compares very favourably with horse costs, a strong case is made out for the employment of a tractor on the average farm.

In addition to cultivation and harvesting work, the use of mechanical power on the farm will certainly increase. This is especially true of general haulage work, both on and outside the farm. The actual costs of this work can be well illustrated by a recent example. An Eastern Counties farmer has kept careful figures, and finds that collecting sugar-beet off the field, carting on main road to a station one and a half miles away, and unloading into trucks, costs him about 4s. per ton. If there is any congestion at the station the cost rapidly increases, and may reach easily 8s. per ton. In addition to this he loses the use of his horses for other work for three of the most important months of the year.

Some form of tractor that will pull larger loads at a greater speed than horses is a self-evident alternative. This implies some easily fixed form of road-bands for the wheels or, alternatively, easily removable strakes. Increased speed is also desirable, not only for road work but for cultivations as well. We have shown at Rothamsted that the soil resistance increases only slowly for a considerable increase in speed of working. Hence, there would be a further economy in land work if the tractor were designed to run at increased speed. Obviously some other factor might have to be sacrificed, or reduced, and the designer would have to make the best compromise, remembering that a working speed undesirable on purely technical grounds may have very distinct practical value.

Any advance of this nature also concerns the implement makers, since the proposed speed of an implement is one of the many factors to be taken into account by the designer. In fact, the general problem of tractor-implement design and construction —at first necessarily an adaptation of existing horse implements— can hardly be regarded as solved. They are designed largely

as separate units to be hooked on to the draw-bar; they are merely drawn by, and in no sense an integral part of, the machine. There is scope here for improvements, and at least one form of plough is now on the market designed for coupling direct on to a tractor. The advantages of easier control by the driver, ability to do neater work, and saving of space at the headlands would be fully appreciated by the farmer.

It is but a short step in theory from a series of cultivation implements that are definite attachments to the rear of a tractor to a single tillage machine that will produce a tilth at one operation. Much work is being done on rotary cultivation in an endeavour to solve the many practical problems of soil tilth. We shall not deal with this; it is the subject of another paper to-day, and our own experiments have already been discussed by the writer at an earlier conference on Cultivation. One aspect, however, must be mentioned. A rotary cultivator and its engine form a single machine, and although it could do belt-work also, it could not in its present design perform haulage work, and serve as a general-purpose machine to the extent that the tractor does.

The directions in which mechanical power will extend on the farm in the immediate future are unmistakable, and the salient features of the machine and its accessories can be written down: a tractor of 10-20 or 15-30 h.p., weighing about 30 cwt., fitted with a belt pulley and a power take-off for direct driving of binder machinery, etc.; a range of cultivation implements, not simply hooked on the draw-bar but properly coupled and closely under the driver's control; the maximum speed consistent with reliability; strakes easily and quickly removable, or covered with a band for road work (or possibly some form of caterpillar tread); and, finally, general reliability and a long working life.

To use such a machine to the best advantage is the farmer's task. He must give it the same attention bestowed as a matter of course on his horses. He must so arrange his horse and tractor work that each gets the type of labour for which it is best fitted, and, above all, he must exploit to the full the capacity of the tractor to do heavier work than horses, at a greater speed, and for a longer time.

Finally, investigation is urgently needed on such matters as deep ploughing, subsoiling and rotary tillage. The tractor has placed the means of doing these operations at our disposal, but we have very little information indeed about the best methods of doing the work, the most suitable designs of implements, and, above all, of the effect on the soil—which, after all, is the most important thing. This forms an important part of our work at Rothamsted. We are studying in the laboratory and in the

field under practical conditions the problems of soil tilth, on which developments of the above nature must be based.

In this brief review of the subject the endeavour has been made to compare and contrast horse and tractor work on the basis of actual performance alone, and the evidence leads to the definite conclusion that mechanical power will, on its merits, play an increasing part in our farming operations.

There are two other factors that will in all probability accelerate this process.

The first is: market for draught horses is rapidly diminishing with the greatly increased use of motor transport, and we seem to be within reasonable distance of the time when the farming community itself will be the only buyers of horses.

The second point is perhaps more debatable, but one wonders whether the traditional method of meeting bad times by taking land out of cultivation and laying it down to grass is going to survive the great development of the cheap imported-meat trade. Farmers met the competition of imported wheat in the 'seventies by laying land down to grass; they may be compelled to meet the competition of imported meat by maintaining their land in arable crops, in which prominence will be given to semi-market-garden crops, for which there is, throughout the country, a large and increasing demand.

THE DESIGN OF A GENERAL-PURPOSE TRACTOR

By H. G. BURFORD, M.I.A.E., M.I.Mech.E.

S. Hampstead

Before dealing with details bearing on the subject of the "General-Purpose Tractor," I think it would be of value to review the development of the Tractor industry that has been steadily taking place during the last two or three years. Unfortunately for all interested, the agricultural industry in this country has gone through very difficult times, and the general position is one of great anxiety. Whilst countries on the Continent are steadily developing the use of the tractor—covering very wide fields of activity, and absorbing them in large numbers—the home requirements are very small and, again unfortunately, supplied very largely from foreign factories. This state of affairs is very regrettable, and when the demand comes from the British agriculturist—as it is bound to do—Britain will

find great difficulty in meeting that demand. In my opinion—which has not changed for many years—the way to restore prosperity to the agricultural industry must be by the employment of mechanized power for every possible requirement on the farm. This opinion is based on the first and important question of *time*, and the necessity —owing to the various climatic changes—of using every available opportunity for intensive cultivation.

The manufacturers of tractors in the past have been met always with the question of producing tractors at a low price, and in many cases to meet these conditions it has necessitated the employment of unsuitable material, with results quite frequently very unsatisfactory to all concerned.

It has been found by experience that to give satisfaction it is imperative that material of the highest quality only should be used.

Assuming that the tractor of to-day embodies high-grade material, with all the advantages of heat treatment and the results of steel research derived from experience gained both during the War and after; and remembering that many manufacturers of tractors are also manufacturers of cars and commercial vehicles, and with their extensive production methods and modern machinery can bring into the tractor business their experience, thereby reducing the cost to a minimum; whilst other firms specializing on the production of tractors in specially equipped shops also have practical experience in productive methods in other branches of their business; based on these facts, the agriculturist, when purchasing a tractor, can be assured that all the ingenuity and skill of the engineer, both as to material and workmanship, are embodied in their latest products.

The question of maintenance and upkeep is being separately dealt with by Mr Watson, so that my remarks will be brief. The extreme conditions under which the farm tractor has to perform its work calls for care and attention from the hands of the user: cleanliness, care of entire lubrication system, periodical inspection and adjustment of all wearing parts, careful attention to all the instructions issued by the manufacturer, and good housing accommodation. Neglect of all or any of these points will be costly, and the results will be dissatisfaction to both user and manufacturer.

Practical experience and study have proved that the worst enemies to the agricultural tractor are dust, grit and lack of attention. Manufacturers are giving great care and study to eliminate the foreign matter from the engine. Not long since it was the general practice to take the air in through the carburettor by means of an open pipe; this led to excessive engine wear. Many devices have been tried, including water filters—*i.e.* the air being sucked through a volume of water. This, however, was unsatisfactory from many points of view, and has been discarded. Trials have

been made with an apparatus fitted with felts of various dimensions and sizes; this system failed for the reason that the operator did not change the felts often enough, and the finest particles were drawn through into the engine, naturally causing great damage. One leading manufacturer of to-day still retains the felt cleanser, but of generous proportions, owing to the position of the radiator. It is realized by experience, which has been gained in countries in Europe where conditions of long periods of drought exist, that to make a tractor at all practical and efficient an air clarifier and oil clarifier are indispensable. The present practice is for an apparatus to be fitted that can be removed easily and cleaned, and in which the air passes over or through a series of plates that have been dipped in oil. At the beginning of each day's work the plates—which are in the form of a cartridge and easily removed—are washed out by paraffin; they are again immersed in oil and replaced. This operation takes very little time, but the results in the reduction of wear on cylinders, pistons and other working parts are remarkable, and will give a much longer life to the most important part of the tractor—the engine.

Another important feature is the filtering of the lubricating oil from the sump of the crank-case. The oil passes through a filter, fitted with felt pads or coils. In this way the oil is cleaned of all foreign matter before being again pumped through the main oil channels. The results of this system add longer life to all wearing parts.

General-Purpose Tractor.—In laying down a definite specification for the above tractor, consideration must be given to the various conditions and requirements that are met with in the various parts of the world; and it is only by close study and careful analysis of these conditions that I am endeavouring to outline what in my opinion a tractor should embody to serve a useful purpose in the agricultural world. The tractor for general purpose on the average farm, in my view, should be of the light type—22 to 30 horse-power, at revolutions not exceeding twelve hundred per minute; four cylinders; good, strong and efficient radiator; gear drive fan and water pump; governed engine; magneto ignition; forced lubrication; crank-case to be of strong design; easy access to all parts requiring adjusting; ball-bearings to be made as dust-proof as possible; two speeds and reverse; all gears to be machine-cut and of highest-grade material, heat treated; rear axle to be of strong design; ample brakes to be fitted on rear wheels for use when on road haulage; weight not to exceed 30 cwt.; to have belt-power and speed capable of driving full-sized threshing-machine or any other implements used on the farm; adjustable draw-bar; facilities for changing spuds or strakes quickly and replacing with solid twin-tyres on rear wheels, single on front without change of wheel; to

be fitted with an air clarifier and oil filter; the front axle to be sprung and pivoted, capable of movement to accommodate wheels on irregular surfaces—in general, a tractor that can be operated easily, economically, and be capable of use for all the various requirements of farm work in general.

There is, of course, a field for tractors of a large horse-power and of a heavier type, but a tractor on the above lines will be found quite sufficient for the average requirements of the agriculturist.

Implements for use with the Tractor.—There is still much to be desired in the question of co-ordination of interests between the implement manufacturer and the tractor maker. At a very important demonstration under the auspices of the French Ministry of Agriture, in October 1927, it was observed that where the implements were doing bad work the blame was put on the tractor, and it was at once condemned. Whereas, actually, the tractor was performing its function of drawing the implement, but the implement was totally unsuitable for the work it was called upon to do. Developments of improved ploughs for tractor use are taking place in France and Germany. The advantages are many: ease of control; mounting close to and integral with the tractor; automatic self-lift; one-way operation; and over-all length of tractor and plough reduced to a minimum.

A few figures of the growth of the tractor use in America since the War may be of interest. The figures below are taken from an official statement made to the Pennsylvania College of Agriculturists:

In 1924 there were in use in that state 18,467 farm tractors and 452,000 horses. Assuming 1 h.p. for each horse and 10 h.p. for each tractor, the horse provided 71 per cent. of the draw-bar horse-power, and the tractors only 29 per cent. The figures given for 1924 compared with 1920—for tractors—show an increase of 224 per cent., as in 1920 the numbers stated to be in use were approximately 5697. The official statement also quotes that savings were effected by the use of tractors, the cost in ploughing being 1 dollar 75 cents. per acre. Given a ten-hour working day the tractor will plough approximately five acres, where the work done by a pair-horse team is approximately two acres. Cotton growers state that on a two-hundred-acre plantation the cost of the tractor can be saved in one year as compared with similar work done with a four-horse team.

In conclusion, it is of the highest importance for the future welfare of this country that every help and encouragement should be rendered to the agriculturist to use mechanical power on the farm. The modern tractor can and will do the work required at lower cost, saving of time, and with increase of crop. In the interest of British agriculturists I trust that the responsible authorities

will give a strong lead to the extended use of the tractor in this country, which will restore the agricultural industry to its right and proper position and so benefit the community at large.

THE CARE OF THE TRACTOR ON THE FARM

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An agricultural machine or implement usually suffers from the simple fact that it is an inanimate object—*i.e.* it is without life or soul. Whilst most owners will give some measure of personal attention to even the meanest and least profitable animal on a farm, there are many who, having bought a machine, turn it over to a heavy-handed individual who has no knowledge of its construction, no interest in its success, and little or no inducement to acquire that knowledge or stimulate an interest.

Tractors may be divided, roughly, into two broad classes—firstly, the petrol or paraffin class; and, secondly, the steam class. I propose to confine my remarks to the former.

If an engine starts up at the first swing and runs with a healthy purr, indicating that all is well, a driver feels that he has made a good start for the day. This feeling of satisfaction is amplified if the engine answers to the throttle, and pulls in the field as though it took a real interest in its work. In the case of an engine that has been in use for any length of time these results are not obtained without trouble, but it is surprising how long an engine will keep in good condition if it receives consistent attention, and all adjustments are carried out as soon as they become necessary. Apart from the actual breaking of a vital part the diseases from which an engine suffers can be classified, roughly, under the general name of troubles, as follows: ignition, fuel supply, lubrication, valves, and water circulation. To this list of evils may be added knocking or noisy sounds, which are not evils in themselves but are simply warnings that all is not well.

Ignition.—It is of vital necessity to keep the coil or magneto free from damp, because if the condenser becomes damp it will not only cause leakage and failure of the ignition but will not hold any charge, and the resulting spark will not be efficient. Great care should always be taken to avoid spilling water over either coil or magneto, and should any be spilt thereon it should at once be

mopped off, and, if necessary, dried off by warm air from a lamp or stove, but care should be taken not to raise the temperature of the part so much as to melt the wax or shellac insulation.

I will now deal with some of the more common troubles experienced with ignition systems:

Misfiring.—The driver who knows his engine occasionally detects an alteration of its note or an interruption of its regular hum. This, if accompanied by a falling-off in power, is probably due to occasional or persistent missing of one of the plugs. When compression taps are fitted it is easy to locate the faulty plug. If all the plugs are firing badly, the fault may be either in the petrol supply or in the ignition. If only one plug is missing, the trouble can at once be set down to ignition alone, or, on rare occasions, to a valve being stuck open.

Faulty Plugs.—Apart from actual damage to a plug by breaking the porcelain or other insulation, there are three main evils from which it may suffer. Short-circuiting may take place between the points and the body, due to the hot spark having melted the metal. The gap of the plug may be too wide; it should not be more than about $\frac{1}{50}$th of an inch, or, roughly, the thickness of the average thumb-nail. If the engine misses when running at small-throttle openings the points of the plugs should be set a little farther apart, whereas, if missing takes place at full-throttle openings the points should be set closer together. The third evil is due to sooting up, and is cured by cleaning with a little petrol.

An occasional cause of missing is through having the points set in a pocket in the valve cap. This pocket remains full of spent gas left during the exhaust stroke, and a considerable improvement can be obtained by fitting plugs with a longer reach.

The Magneto.—The magneto may be the cause of irregular firing in any or all of the cylinders, but tampering with a magneto is a pastime not to be recommended unless a driver understands it. There are two points, however, to which occasional attention is required, these are the high-tension distributor and the contact breaker. This distributor disc should be cleaned occasionally with a cloth and a little petrol, and the disc wiped over afterwards with a trace of oil. The contact breaker is the most important part of the mechanism. The space between the platinum points when they are separated should be about $\frac{1}{64}$th of an inch, and any variation from this may cause ignition trouble. The contact points should be trimmed when necessary with a very fine file, so that they bend together level when closed, but they should not be trimmed unless the points are uneven. Oil should not be put on the platinum contacts, or it will cause them to burn away rapidly, Occasionally the lever to which the moving point is attached works stiffly, allowing the points to remain apart; in such a case the fibre bush should be

eased slightly. Oiling is of no use, as it may make it swell more. If these various points receive proper attention, there is little to go wrong.

A few warnings concerning magnetos:

Don't run the engine with a plug wire disconnected—you may ruin the insulation. If you want to cut out a cylinder, short-circuit the plug—that is, connect it directly to the metal of the engine.

Don't swamp the magneto with oil—two or three drops of good oil once a week are sufficient.

Don't oil the contact breaker.

Don't use an oil-can with dirt on the spout.

Don't file the contacts more than is absolutely necessary.

Don't hold the contact breaker to prevent the spindle turning when tightening up the nut of the driving coupling.

Don't fail to see that the earth wire is not making a short-circuit.

Don't hang plug cables on the exhaust pipe.

Don't replace plug wires on the wrong terminals.

Don't tamper with a magneto unnecessarily.

Motor Fuels.—Every driver knows that if petrol is poured on the hand it evaporates with a marked cooling effect, due to the petrol extracting heat from the hand. In a carburettor, fuel is supposed to be split up into a fine spray, and the heat for its vaporization is extracted from the air. Any cracks or leaks in the pipe which heats up the air to the carburettor should be repaired at once.

The jets in a carburettor are usually very small, and it is very necessary that all the fuel should be carefully filtered before it is put into the tank; as an additional precaution there should be a filter between the tank and the carburettor. These filters should be cleaned regularly, and any drops of water found therein carefully blotted up.

"Popping back" into the carburettor indicates a weak mixture, and is one of the first symptoms of fuel-supply trouble. Such a mixture burns slowly, and may still be burning when the inlet valve opens, thus allowing some of the burning gas to rush back into the carburettor. If the engine has been running normally and popping suddenly develops, look for some stoppage in the fuel supply. First try the float needle, and if the petrol does not flow into the float-chamber, although there is plenty in the tank, there is undoubtedly a stoppage in the pipes or the filter, both of which should be thoroughly cleaned. Such stoppages are frequently caused by small particles of scale from the tank, pieces of waste or fluff, or by drops of water which will not pass through the filter or the jets. Many engines have a tendency to pop back when

first started, from cold, but work satisfactorily after they have run a little time and become warm. The explanation of this has already been given in the paragraph dealing with hot-air supply.

Occasionally a float sticks, or is held up by grit, or the needle becomes bent or jammed, causing the carburettor to flood. Flooding may also result from a punctured float, in which case the petrol can be evaporated and driven off by immersing the float in hot water, and at the same time the issuing bubbles will show the position of the hole, which should then be soldered neatly, or, in the absence of solder, a temporary repair can be made by wiping a piece of soap over the hole.

A leaky joint in the inlet pipe may cause much trouble by weakening the mixture, and in an old engine leakage of air along the valve stems, due to wear in the guide, may have the same results. All joints should therefore be kept tight and leakages stopped as far as possible.

Very briefly, fuel-supply troubles and their remedies may be summed up as follows:

Engine pops back and stops: no petrol in tank, petrol pipe choked, filter stopped up, or water in petrol.

Engine pulls badly on hills: insufficient heating, or jet too small.

Engine flabby and exhaust offensive: jet too large, causing rich mixture.

No acceleration and engine staggers when throttle is opened: engine cold, or mixture too weak.

Carburettor floods: needle valve sticking, dirt under needle, valve or float punctured.

Consumption excessive: engine or transmission in bad condition, jet too large, ignition retarded, leakage of petrol, or brakes binding.

Let me here give a word of warning to drivers. A carburettor is a delicate piece of mechanism, but if properly fitted and treated carefully it rarely gets out of order. No driver should be misled by an engine knock to believe that there is something wrong with the carburettor, as under no circumstances can this be the case. Again, many drivers always blame the carburettor if an engine suddenly heats up, whereas the probable cause is that the fan belt is slipping, that there is no water, that the water-jacket is choked up, that more oil is needed in the crank-case, or because the ignition is retarded too much. Overheating is never caused by too much gas.

Lubrication.—Lubrication means the introduction of a separating film of oil or grease between two parts of a machine which have movement one upon the other. If the moving parts make actual

metallic contact the surfaces will soon become roughened to such an extent that they may seize. The higher the speed of rubbing the sooner seizure will occur, and its consequence will be more serious.

Some parts of motor vehicles are designed so as to create friction, but such parts are few, and are for special purposes—such as the main clutch, the brakes, the fan belt and the tyres.

Of all the sources of friction in an engine, that of the piston against the cylinder wall is the largest item, and is double or treble the total friction of all the other parts of the engine put together.

Valve Troubles.—Valve trouble is usually indicated by a gradual falling off in power. On examination the valve faces will be found scored and pitted, and it is necessary to grind them down on to their seats to again produce a clean face. If the face is very deeply pitted, it may be necessary to clean it up in a lathe, after which it should be ground to a true bed on the seating. In an old engine the seatings themselves may become rough, and necessitate truing up with a special tool, or, if not too bad, an old valve can be used for this purpose with a slightly coarser grade of emery, finishing off with fine emery and the proper valve.

The operation of grinding is a perfectly simple one, but requires to be done with care. Only the very finest flour-of-emery powder, mixed with lubricating oil to form a thin paste, should be used. This should be spread evenly on the valve face, and under a slight pressure the valve turned first in one direction, then in the other, occasionally lifting it and turning it through about half a turn before letting it drop on the seat again. This is to prevent the emery getting into tracks. If a light spring is slipped under the valve head, and is long enough to lift the valve from its seat, it will be found a great convenience, as on relieving the grinding pressure the valve will be lifted and it can then be twisted as much as is necessary before pressing down again. The exhaust valves suffer most, due to the hot gases sweeping across their faces, and it is for that reason that one usually allows a little more clearance for the exhaust-valve tappets than for the inlet-valve tappets, so as to make quite sure that the valves really do close. When grinding in valves it is of course necessary to take care that none of the emery paste enters the cylinder or gets on the valve stem, and the valve, valve port and guides should be thoroughly cleaned before reassembling the parts, oiling the valve stems during the process. After regrinding valves it is usually necessary to readjust the tappet clearances, carefully tightening up the lock-nuts so that they cannot work slack. Each valve should be examined in turn to make certain that it is never held off its seat, nor has too much clearance—the clearance should never be less than $\frac{1}{64}$th of an inch, and never more than about $\frac{1}{32}$nd of an inch—but in order to get the quietest and best running it is advisable to adjust the

tappets while the engine is still hot and the valve stems expanded to their maximum amount. It is not always easy to see if the clearance is right, especially if the head of the valve tappet is much bigger than the end of the valve; the tappet head may be a bit soft, and the end of the valve then punches a slight depression into it, so that the clearance is really more than it appears to be. It is, however, always preferable to have too much rather than too little clearance, as, although the engine will be noisy, there is less fear of burning out the valves.

If for any reason a camshaft has to be removed, careful search should be made for any marked teeth, and care exercised that the teeth of the timing gears are again correctly meshed when putting the camshaft back again. Occasionally, a valve sticks in the guide, due to insufficient lubrication, or it may be that the valve stem has warped. If a spot of oil on the stem is not sufficient to make it operate again the valve should be removed, and the stem rubbed down with a piece of emery cloth, or, if badly warped, carefully straightened in the jaws of a vice, after which it may be necessary to regrind the valve on to its seat. If the engine is provided with screwed valve caps the threads should be smeared with graphite and oil before replacing the caps, otherwise they may seize and be very difficult to remove. A driver should make quite sure that these are screwed up quite tight, and that there is no leakage. A simple test for leakage is to pour a little oil round the joint when the engine has been started, when any leakage will be at once apparent by the oil being blown away from the joint.

Cooling.—In small engines it is possible to rely on air-cooling, as on motor-cycles, but in larger engines a water-jacket is provided, and water circulated through this either by pump or natural circulation. In most cases it is usual to provide a fan to assist the cooling of the water as it passes through the radiator, and the fan belt should be kept at the proper tension, otherwise there will be slip.

Water-cooling troubles make themselves evident by steam being generated, but so long as steam is not blowing away, even if the radiator is uncomfortably hot to the hand, there is no danger, as an engine works best when the water is just below boiling-point. Like most complaints of engines, overheating may be of gradual growth, or it may develop suddenly. In the former case it means that the water-jackets and radiator have become coated with scale such as we find in a domestic kettle, except that the scale may also include rust and grease. Scale interferes with the passage of heat to a very great extent, but much of it may be removed by filling the jackets with a hot strong solution of common soda, then after leaving it to stand all night, drain it off, and thoroughly wash out with clean water. Soda must not be used if the radiator or pipes

are made of aluminium, because soda is injurious to this metal. In such a case it is better to use Boilerine Tablets, or a solution of carbon tetrachloride.

If overheating shows up suddenly on an engine that has previously given no trouble, we must look for a broken or slack fan belt, a faulty pump, or leaking joint allowing water to escape, or the accidental opening of a drain tap. The most serious cause of overheating, however, is a cracked cylinder, as a very minute crack will allow gas to escape from the cylinder into the water-jackets, and the water will quickly boil. Some drivers appear to have difficulty in making tight joints in rubber connexions, but if a little rubber solution is smeared on the pipe it will not only act as a lubricant, but when it sets it will ensure a good joint.

Transmission Gear.—The transmission gear commences with the clutch and finishes at the road wheels. The two main portions of a clutch should disengage positively when the clutch is out, so that there is no dragging on the gearshafts. If the clutch becomes greasy it will slip, causing heating, and probably burning the lining, while if it is allowed to become fierce, it makes starting difficult, and throws undue load on the transmission system. A slipping clutch may be caused by insufficient spring pressure, the lining being badly worn, or worn so as to leave a ridge which prevents the cone entering any further, in which case the ridge can be removed with a chisel, sharp knife, or file. If none of the above causes is present, but the clutch still slips, a new lining should be fitted as soon as possible. Meanwhile, as a temporary expedient, thin strips of metal can be inserted underneath the lining between the rivets. A fierce clutch may be caused by too much spring pressure, or by the rivet heads standing proud of the lining, in which case the clutch will slip a little at first, and then take up suddenly. The remedy is to drive the rivets further in with a punch, so that they are below the surface of the lining. Another and frequent clutch trouble arises from the centre or spigot bearing becoming so worn as to allow the clutch cone to sag, and fall out of truth with the fly-wheel. This makes gear-changing a very difficult matter, because the clutch is never really free. If a clutch slips badly, the first thing to do is to wash the lining with petrol, and if the lining is of leather it should then be reconditioned by dressing it with castor oil or collan oil and leaving it to stand disengaged overnight, so as to allow the oil to soak in. If, however, the lining is of fabric, no oil should be put on it. As a temporary measure for a slipping clutch, it should be dusted over with fuller's earth, or, in the case of a fierce clutch, with powdered graphite, or french chalk.

Multiple-disc clutches are now frequently used, some of them being enclosed in an oil bath, whilst others are of the dry type. In

the oil-bath type the case should occasionally be drained and washed out with paraffin and new thin mineral oil then put in. If thick oil is used it is liable to become sticky, and may cause slipping, whilst mixtures of engine oil and paraffin should never be used.

Between the clutch and gear-box many vehicles are provided with a small brake or clutch stop, the object of which is to bring the rotating parts of the gear-box to rest when the clutch is out, so as to make gear-changing easy. Attention should be paid to this small brake to see that it is neither too fierce nor too slippery.

The next link in the transmission is the change-speed gear-box. It should be supplied with the right quantity of suitable oil and occasionally drained, washed out with paraffin, and a supply of fresh oil then added. This cleansing and replenishing is necessary because, no matter how carefully used, fine particles of metal dust or chippings become separated from the gears, bearings, change-speed forks, etc., and if allowed to accumulate they cause extensive damage. The ideal lubricant is a good heavy mineral oil, but unfortunately some boxes will not retain it, and in such cases it is a common practice to mix oil and grease together; neither must be of the kind which produces a soapy mixture, because this implies the presence of acid, which will etch highly polished surfaces and cause damage. As a general rule the thinnest mixture of lubricant the box will retain should be used, not only because it flows freely to every part, but because it offers less resistance to the gears.

From the gear-box the drive is transmitted to the driving wheels through chains or a propeller shaft to the rear axle. If chains are used, it is useless to attempt to lubricate by pouring oil on to them. The only effective way is to remove the chains, wash them thoroughly in paraffin, drain them, and then soak them in a bath of hot grease and graphite, and again drain them. Any excess of grease should then be wiped off, or it will collect dust and grit. If chain-cases are provided they should be maintained in an oil-tight condition, and the oil kept up to the proper level. The chains should be kept at a proper tension—a little slack, but not slack enough to flog.

If universal joints are not properly lubricated, wear will take place, and backlash develop and damage all keys and gearing. The back-axle or differential case requires the same attention as is given to the gear-box. If pieces of metal are found on filtering the oil drained from casings, something is wrong, and the matter should be reported at once, or serious damage may follow.

Conclusion.—As a final word let me add that the best possible way of reducing the cost of maintenance of a tractor is by giving close attention to the matters which I have mentioned. If this is done, and the brakes and steering connexions are kept properly adjusted and all nuts and bolts kept tight, there is little to go wrong

in a modern machine, apart from fair wear and tear, calling for the replacement of worn parts by new ones. If the care which I have advocated is not given regularly, abnormal wear and tear will take place, heavy costs for renewals will be incurred, and the value of the machine will rapidly depreciate. I would again urge owners of tractors to treat their machinery as they would treat their animals. If they do so, they will find themselves well repaid.

PRACTICAL EXPERIENCE OF POWER ON THE FARM

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I propose to deal in this paper with the application of power in my immediate district, and chiefly on my own farm of 330 acres, of which about 225 are under cultivation. The soil is a sandy loam, and with three exceptions the fields are fairly level. The farming in the district is based chiefly on corn, cattle and sheep; there are some farmers who produce milk, and some grow potatoes on part of the root break. My practice has been to depend chiefly on the live-stock department—on sheep, pigs and poultry—and on the arable land; to widen the range of crops by growing a considerable acreage of potatoes, carrots, parsnips, peas and green vegetables, in addition to corn and the usual roots. I have grown sugar-beet during the last three years. My farming, therefore, may be described as semi-intensive—organized, it may be added, as a business proposition.

The following figures, extracted from the annual reports of the Ministry of Agriculture, show a steady decline in the number of horses on farms in England and Wales:

Horse-Power

	Horses, Mares and Colts	*Acres of Arable Land*
1911-1915	1,165,000	11,131,000
1916-1920	1,134,000	11,805,000
1921-1925	1,064,000	11,144,000
1925	967,000	10,682,000
1926	927,000	10,548,000
1927	894,000	10,310,000

The decline in numbers is evidently related to the shrinkage in the area of arable land, but the introduction of the commercial motor for industrial haulage has restricted very considerably the market for horses, resulting in a considerable fall in the number of foals bred on the farm. The Ministry, however, draws attention in the 1927 returns to the fact that the decline in breeding has been nearly stopped. Are we to conclude from this that horse-power in industry and on farms has been brought down under present conditions to the lowest point compatible with efficiency? It may be so; I am afraid, however, that I cannot give a satisfactory answer.

What are the chief reasons for the retention of horses on the farm? The reply is that horses are a handy and really effective source of power. They are the farmer's trusty friends in all weathers, and in all situations—on wet land, on sloping or hilly land, in chain work or shaft work, and are always able to give reliable service. They are slow, but they are very sure.

Cost of Horse per Working Year

	£	s.	d.
Food	25	4	0
Shoes, repairs to harness and sundry expenses	6	5	0
Risk	4	0	0
Depreciation	4	0	0
	£39	9	0

I find, therefore, on my farm, where it is possible to work horses about 260 days in the year, that the cost per day is about 3s.

Cost of Ploughing per Acre

	Acres per Day	s.	d.
Two horses with one-furrow plough	$\frac{3}{4}$	18	0
Two horses with one-furrow plough	1	13	6
Three horses with two-furrow plough	$1\frac{1}{2}$	11	0
Three horses with two-furrow plough	2	8	6

By using a three-horse team and a double-furrow plough the cost of ploughing is brought down very considerably, and the same principle can be applied with economical results to other implements. One of the most recent improvements is the "Gower" two-horse root drill. It is adapted for sowing mangolds, sugar-beet, swedes, and similar seeds, over four rows at one operation, thus covering the ground at twice the speed of the ordinary mangold drill; a further gain being that the ridges are made at the time of sowing.

Each ridge is made by two concave breasts converging from front to back, and the seed is deposited at the required depth immediately in front of the closing ridge. A special feature of the "Gower" drill is its capacity of working when the surface is wet after a shower.

Another valuable implement for ridge work is the pole ridger, carrying three bodies, which reduces the cost of ridging for potatoes by 50 per cent., and earthing-up by 66 per cent.

There is no reason to believe that the efficiency of horse-drawn implements will not be increased still further.

Engine Power on the Farm

Steam Tackle.—Steam ploughing and cultivating in this district are usually done by contract, the price per acre being 16s. to 18s. for ploughing, and 15s. to 16s. for cultivating twice, and 8s. per acre for harrowing twice. The farmer provides the necessary water and about 15 cwt. of coal per day.

The cost per acre is evidently not less than with horses, but there is of course the very decided advantage of rapid execution of the work.

The charge for mole draining is 9d. per chain, measured along the drain.

Tractors.—Tractors are now within the financial capacity of the average man, and it is probable that with the general-purpose tractor we shall see very considerable developments in the near future. At the present time farmers have not quite sufficient confidence in tractors; they know of too many now lying on the scrap-heap, and they know also of heavy bills for repairs, and of much valuable time lost in waiting for renewals of broken parts. Depreciation is a very heavy charge against the tractor. At their best, however, tractors are invaluable in times of pressure because of their speed and of their capacity for working continuously over long periods when it is necessary for arrears of work to be overtaken, or to make the most of periods of favourable weather.

During the last seven years I have used a Wallis tractor, which I have found comparatively easy to handle; it has sufficient speed and power, and is evidently economical of fuel. It is able to travel fairly well on loose ground, and, speaking not as an engineering expert, I have always considered that this power of easy travel is due to its light weight, to the width of its wheels, and its wedge-shaped gripping spuds.

The most suitable kinds of work for a tractor are, in my experience, the hauling of the two-furrow plough, the cultivator, and the self-binder; for belt-work it is excellent. In ploughing there is a certain loss of control over the plough itself—operated as it is from

the front—and this lowers to some extent the efficiency of the work, especially on ground sloping sideways. I have not found harrowing and rolling very suitable work for the tractor because of the wheel-tracks, especially after crops have been sown, as subsequent harrowings fail to touch the young weeds growing along the tracks, and grass and clover seeds falling on these tracks are difficult to cover with sufficient soil. The hauling of the grass-mower has not been quite satisfactory; the wheels of the tractor travel along the edge of the swath, compressing the newly cut grass and rendering the work of the swath-turner more difficult. This defect could be improved by a more careful co-ordination of function between tractor, mower, swath-turner and horse-rake. A further difficulty has been the breaking of the cutting knives and several axles. A point in favour of horses is that they usually pull up when obstructions are met with, and the bill for repairs is correspondingly less than when tractors are used. Perhaps our implement makers will design a more suitable mower?

The hauling of the self-binder is perhaps the most suitable harvesting job for the tractor, as this is killing work for horses on hot days. My binder is a Massey Harris, and cuts a width of six feet. The speed attained is greater than with horses, and the knives cut smoothly in consequence. There have been no breakages due to the tractor which could not equally well be due to horses. There is a loss of cutting width when turning the corners, and it has been necessary for the man in attendance to cut them back with the scythe. There is a device, I believe, which enables the binder to cut the corners more completely, but I have not seen it in use. In difficult cutting, or in a crop of variable length, it is necessary to have a man or a boy on the binder itself; the driver of the tractor, however, being frequently able himself to manage the work of cutting after being well started.

The question of designing wider implements for tractor use in corn and grass harvesting has often been in my mind; but for English conditions and with crops which are often above the average it is difficult to see at the moment how these heavier crops could be handled economically by such implements. It would be a much simpler proposition with lighter crops, and in such cases wider implements could be operated with advantage.

The Tractor of the Future.—The improved tractor must, in my opinion, be of the general-purpose type—of light weight, of simple construction, easy to start, handy in the field and well protected from dust and grit, both inside the engine and about the bearings of the travelling wheels. The tractor must be powerful enough for the work, with low fuel and oil consumption, not too noisy when working, and backed by an efficient repair service.

The driver's comfort must be considered; a suitable platform

and seat must be provided; the driving wheels must also be well guarded to keep the dust away from the driver in dry weather.

This improved tractor must be in the charge of a capable man, sufficiently skilled to keep the tractor running under reasonable conditions. When the tractor is in the shed it will be necessary to provide him with suitable alternative work, which will stand the higher rate of wages that must be paid him.

Cost of Working a Tractor.—The cost of ploughing with the tractor does not appear, in my experience, to be cheaper than with horses when the latter are pulling a two-furrow plough. I have not kept complete costings, but my driver has given me the following figures for fuel and oil consumption for a 21-acre field which, in comparison with the figures for other fields on the farm, seem to be typical: paraffin, 25 gallons; petrol, 5 gallons; lubricating oil, 4½ gallons, and about 1 lb. of grease.

Depreciation works out at about £45 per year, and, allowing 90 working days, the average figure is 10s. per day. As ploughing is heavier work than binding I propose to charge the ploughing at the rate of 12s. 6d. per day, and the lighter work at 7s. 6d. per day.

Repairs have averaged about £18 per year, which equals 4s. per day. I propose to charge 5s. per day against the ploughing.

Summary

	s.	d.
Fuel, oil, etc.	2	3
Depreciation (2½ acres per day) . .	5	0
Repairs	2	0
Wages (piece-work)	3	0
Cost per acre	12	3

If we assume that the charge for repairs is the same per day whether a larger or smaller area is ploughed, we can bring down the cost per acre from 12s. 3d. to 9s. 9d. by increasing the area ploughed from 2½ acres to 4 acres.

Harvesting.—The cost of cutting and tying the same field when in oats worked out at about 6s. per acre when calculated at the rate of 10 acres per day, and about 5s. 2d. per acre when 15 acres are cut per day, which is about the same cost as with horses.

Thrashing.—For belt-work I have found the tractor most satisfactory. As against the steam engine, the tractor depreciates more rapidly, and is not so useful in moving the thrashing-box. The drum appears to be operated as steadily with the tractor as with the steam engine, and in fuel consumption the tractor has a distinct advantage. About 5 gallons of paraffin and ¾ gallon of petrol appear to be sufficient for a day of eight hours, and with steam the

coal consumption is about 15 cwt. per day, and, in addition, water must be constantly supplied. The cost of fuel in the case of the tractor is about 5s. 6d., and, allowing 5s. for the heavier depreciation of the tractor, we have the total of 10s. 6d. against, say, 20s. for coal and 5s. for the work of carrying water, making a comparative figure of 25s. for the steam engine. For thrashing on the farm the tractor is undoubtedly an economical power unit. The sawing of timber for firewood in winter is a side-line of considerable importance.

Motor Cultivation.—I have often wondered why so little progress has been made with motor ploughs and cultivators, as it seems that control from the rear has distinct advantages. As a grower of roots on ridges of various sizes I have often seen the young growing plants damaged by the treading of horses. If one had a very light motor-cultivator which could travel between the rows, and operate tines, blades, discs, or other attachments, a great deal of damage could be avoided. Plants in the field may, of course, be destroyed in other ways than by horses, but it is important to realize that, in the case of sugar-beet, with roots having an average weight of 1 lb. (not very large roots), growing uniformly in rows of 18 in. and singled at 9 in. apart, the crop would weigh 17 tons per acre, which is about double the average yield, and indicates that considerable loss occurs in most cases.

Haulage of Farm Produce

I claim to be a lover of horses, but after being thrown headlong into the road on more than one occasion I was driven to the conclusion that it was safer to drive a motor-car than a horse along the surface of a modern road and I made the change-over, though with some reluctance at the time.

Now, I have also taken the farm horses off the road, and the haulage to station and market is done by hired motors.

My nearest station is four and a half miles away, and a local lorry owner has undertaken to haul manures, feeding-stuffs, and various kinds of produce in bags, at the rate of 4s. per ton, but it appears that a powerful competitor will shortly offer to do the same work at a lower rate. The usual load at the 4s.-per-ton rate is from 25 to 30 cwt., but occasionally 2 tons.

By using horses and moving a crop of potatoes at the rate of 7½ tons in two days with one team, I estimate that the cost per ton would be about 3s. 9d. per ton—slightly lower than with the motor. Owing, however, to the greater speed and convenience of the motor, I prefer to keep the horses working on the land.

Sugar-beet is collected from the farm by the railway company's own lorries, unloaded at the station into railway trucks, and sent

by rail to the factory at Kidderminster, at a cost of 3s. 10d. per ton for collection to the station, and 3s. 6d. per ton for railway freight, which makes 7s. 4d. per ton from farm to factory. For road haulage a contract price with a private firm was 7s. 6d. per ton from farm to factory. I have reason to believe that both these contract rates will be lower during the coming season. The beets have, of course, to be carted from the fields to a loading deck adjacent to the hard road, and assistance is given when loading the lorry at the deck.

Summarized haulage costs to Station—4½ miles distant

Horses (2½ ton loads)	3s. 9d. per ton
Light motor-lorry (1¼-1½ ton loads)	4s. per ton
Heavy motor-lorry (6 ton loads)	3s. 10d. per ton

My chief market town is Wolverhampton, which is fourteen and a half miles away. The following figures represent the charges from the farm to the market and to various depôts in the town:

Potatoes in bags (2 ton loads)	8s. per ton
Potatoes in hampers (2 ton loads)	10s. per ton
Carrots, parsnips, peas and cabbages (1¼ ton loads)	10s. per ton
Sheep and pigs (about 15 sheep)	15s. per load

An economy of some importance resides in the fact that these light lorries can take their loads of from 25 to 30 cwt. direct from the field, except when the ground is soft immediately after rain, when it is necessary to bring out the horse, and cart the load to firmer ground. Heavy motors must always remain on the hard road when being loaded.

The cost per ton when produce is sent to Wolverhampton by road to the station, and thence by rail, is about 15s., delivered to the market, which is, of course, quite an impossible figure.

Summing up, it will be seen that it is still difficult to reduce the cost of many kinds of field work to a point lower than is possible with horse-power, yet I am convinced that a general-purpose tractor, used in conjunction with horses, is a combination which under present conditions gives that variety of power which makes for high efficiency on our medium and large-sized arable farms. There are times when the value of the work done, say, during a spell of favourable weather, makes the actual cost of the job seem extraordinarily well worth while, and these are the times when the tractors give their best service, which may in some cases mean the difference between success and comparative failure.

For road haulage, horses are too slow, and are rapidly being

superseded by motors. I feel, however, that it is better for most farmers to hire rather than to purchase a motor, as, in these days of telephones, there is no difficulty in bringing a motor to the farm almost at any time, which is a wonderful convenience.

In conclusion, it is obvious that mechanical power applied to agriculture is an important factor making for the improvement of farming conditions—a factor which may prove to have a very special appeal to the oncoming generation—and if in this way we can raise the standard of life on the countryside it will be due very largely to the skill and resource of our agricultural engineers. I hope that their efforts on behalf of agriculture may still further result in "better farming, better business, and better living."

ROTARY TILLAGE

By R. D. MOZER

Simar Rototillers

The subject of "Rotary Tillage" is not a simple one and is not easily condensed, and I must confine myself to stating a few facts and deductions which may prove to be the basis for subsequent developments of this intricate matter. In certain phases of farm management the question is relatively simple—harvesters, automatic milking machines, and many other power-driven implements are manufactured along more or less standard lines, and often there remains only the problem to choose such machines as will give long life and continuous service.

In the department of tillage operations, however, the problem is more difficult. As a general rule, the farmer knows instinctively that such-and-such processes will yield certain results, but there is a wide gap between the process and the final result, and he is accordingly loth to change anything from his former methods, because he cannot foresee step by step what effect will follow the introduction of new methods at any stage of his operations. Hence the difficulties facing the agricultural engineer are very acute.

The first problem to be faced in connexion with the application of power to tillage operations is the nature of the power which should be used, but that is a problem which is beyond the scope of this paper. The second problem is whether the mechanical unit should be designed so as to make use of conventional tillage implements, or whether the implements themselves should be re-designed to fit in, as it were, with the usual consequences of the generation of power by mechanical means. Within the latter category we find

only one class of implement, known in general terms as "Rotary Tillers."

There are, of course, considerable variations between the different rotary tillers, and in general there is a broad distinction to be drawn between those with rigid tools and those with elastic tools. All rotary tillers have for their object the production of a seed-bed in a single operation, and a machine capable of giving such a result without counteracting disadvantages must find its place wherever soil is to be tilled.

Mechanical power being essentially rotary in character, it is only logical to assume that such power should be employed in its original rotary form in connexion with the work of tillage. A simple illustration will suffice. In general, the axis of the rotary tilling unit is parallel to the main axle of the propelling wheels; it corresponds to the back axle of a car, and has a rolling action with the qualification that a certain breaking effect is caused by soil resistance and other factors. Most of us, however, as novices in the art of car driving, have forgotten to release at some time our hand brake and have only experienced a reduction of the maximum output of the engine, and by no means a complete extinction of power.

What probably constitutes the first recorded vision of rotary tillage as an accomplished art is to be found in the pages of Hoskyn's book *Talpa; or, The Chronicles of a Clay Farm*, written when steam-power was being adopted very largely in industry generally. Hoskyn foresaw an implement which, to use his own words, would be one "which completed the whole work of tillage as it moves along" and, "in one comprehensive act—and word—cultivation." Since the time of Hoskyn much has been said and done in the field of rotary tillage, yet it cannot be said that the results achieved, so far as a general adoption of a machine of Hoskyn's conception is concerned, are in accordance with the simple logic underlying the author's words. We need to examine in some detail the reasons why rotary tillage has not been adopted more widely than is actually the case, and it is unbelievable that this method will not be given at least the extensive trial which it deserves, so that the claims of its sponsors should at least be proved or disproved.

The introduction of mechanical power to the farm was in the form of tractors, and rotary tillers only made their appearance in this country after the War. Since the introduction of the latter machines a strong controversy has been carried on as to the respective merits of the two power units as compared one with the other, while each in turn is the subject of comparison with the horse.

Rotary tillers are generally specially designed, self-contained machines, and while modifications in design are usually possible to permit of the use of the power for such purposes as belt-work, etc., they do not at present replace horse-power to the same extent as do

tractors. Nevertheless, it should not be impossible to effect modifications of design to rotary tillers to widen the field of usefulness of such machines to cover most farm operations.

It may be said that all the considerations which are leading to the replacement of horse-power by mechanical power in industry generally, apply, with a few modifications, to agriculture. The horse is an imperfect power generator because it consumes independently of the power supplied and whether required to generate power or not. Again, the horse consumes part of the products of the soil, and is in consequence an adverse economic unit, especially in the case of relatively small farms.

The tractor is uneconomical because, in order to get the necessary adherence, it must be given weight on the driving wheels or track. To drag a plough consuming effectively 4 h.p., a tractor weighing about 18 cwt. is wanted, which practice has shown to require an engine of at least 14 h.p., so that there is a waste of some 70 per cent. of the power generated.

This weight-cum-adherence problem is largely centred in the fact that the plough as used with the tractor exerts a backward draught. Similar considerations need not apply to rotary tillers, where the action of the revolving tines helps the whole machine forward. There is, consequently, a very much lower loss of power between the point of its generation and that of its application.

Nevertheless, rotary tillers so far produced—except the smaller types up to about 10 h.p.—have been wrongly evolved in not taking advantage of all the weight reduction which is possible. It must be admitted with some reluctance that there is at present no rotary tiller which is really fit for the farmer, and that only those more suitable for the nurserymen, etc., are at present sound commercial propositions.

The problem from the agricultural standpoint is a question of the respective merits of the plough and the implements which normally follow it, on the one hand, and the rotary tiller on the other hand. Here we are concerned only to find the best means to produce a tilth or seed-bed. On a properly managed farm the cost of seed-bed making represents about 10 per cent. of the crop value, and a 10 per cent. increase in yield as the result of better or more timely work would therefore cover this part of production costs.

Rotary tillage can effect much greater saving than this, as, for example, by eliminating several operations, by better utilization of manures—which are more uniformly distributed—and by a reduction in the amount of manure required.

The specific weight per horse-power of rotary tillers can be reduced to a minimum, and this reduction means that there is less compression of the soil. A distinction can also be made between the low compression of the soil and the low-friction effect of a set

of independently mounted tines, and the comparatively high friction between the plough and the solid earth which it is required to turn over in large masses.

The fact that the work of tillage is completed in one operation with the rotary tiller is an unquestionable advantage in spring cultivation, and, as seeding is the only operation subsequent to tilling, compression of the tilled soil is still further reduced. Again, the action of the rotary tiller is such that instead of the hard, smooth pan which is left by the plough, the bottom of the tilth is left rough, obviating the necessity to subsoil and permitting percolation of water during rainy periods, to be stored as a reserve for the top soil. Next, it is claimed that the tilth produced with the rotary tillers is a much more uniform and a finer one than can be secured by any other means, with the possible exception of very careful hand labour. The fine even texture of this tilth is productive of better aeration, while it is of considerable assistance in promoting free and rapid root growth.

The principal criticism against rotary tillage is its unsuitability for autumn cultivation. It is thought that because the tilth produced is such a fine one there will be a tendency, with heavy winter rains, for the soil to pan down and set hard. This is a point on which there is much conflicting evidence that must be carefully sifted before any general verdict can be passed. In any case it should be possible to modify the design of the tiller to enable a much coarser tilth to be obtained at will.

The question will be asked as to what evidence there is in practice that the claims for rotary tillage are justified. In the commercial field, rotary tillers are now comparatively well known amongst fruit-growers, market-gardeners and nurserymen, and have justified themselves to a much greater extent in connexion with intensive farming than with farming in its more general aspect. This is not surprising, since the principal objection to rotary tillage—namely, its probable unsuitability to autumn tillage—does not apply in this particular sphere. On the other hand, all the admitted advantages of rototillage apply. Market-gardeners require a fine seed-bed, ability to catch the weather, and facilities for sowing a fresh crop immediately the preceding one has been harvested.

As applied to the raising of root crops, very favourable reports are available, and one case is recorded of rotary-tilled soil yielding a potato crop of 30 tons to the acre. Very favourable results have also been secured with swedes, turnips, mangolds and sugar-beet. On the other hand, a conflicting experience was obtained at this Institute, where swedes were grown in three plots which had been respectively horse-ploughed, tractor-ploughed and rotary-tilled. The latter plot at first gave every promise of being the best crop of the three. Suddenly there occurred a marked change. The soil

became "panned" or hard, the appearance of the foliage fell away considerably, and, in the final result, the crop was inferior in weight to that of the other two plots. My company has been invited to participate in further experiments at this Institute to ascertain whether this apparently deleterious effect of rotary-tilling can be overcome by the simple expedient of inter-cultivation at defined stages during growth. If, with one additional passage with the rotary tiller, with its tines set shallow to skim the surface, the pan can be quickly and effectively disturbed, there will be an answer to the somewhat widespread belief that the rotary tiller is unsuitable as an autumn cultivator.

Leaving once again this rather controversial field we can give a few moments' consideration to other points where the rotary tiller is of undoubted benefit. By a simple depth-regulation arrangement it is possible to use these machines, not only in the preparation of the soil for seeding, but for cultivation at all stages of growth. In the summer months they can be used to promote a fine surface mulch which is of such great benefit in helping to tide over the effects of scarcity of rainfall. They will deal efficiently with weed growths of variable natures, though it is to be noted that repeated cultivation is the *modus operandi* for destroying these pests effectively, for, unless frequent cultivation is resorted to, a marked increase in weed growths is noted, which is incidentally a finger-post pointing to the possibilities of rotary tillage as a fertilizing method.

Reviewing the field covered by this new method it may be stated that rotary tillage is an accomplished fact in certain departments. It exists as a fully evolved commercial force in such work as nurseries and for specialized crops, and it is extremely useful in its present form for certain farming operations requiring intensification of methods. The larger types of existing rotary tillers represent by no means the last word, and we may say that, so far as general farming is concerned, rotary tillage is still in its infancy. It is doubtful if there is one agriculturist who is not sufficiently far-seeing to watch with interest the developments in the practice which are bound to take place during the next few years, and, to quote Hoskyn once more: "In the Arts as well as in morals, difficulties are opportunities."

ELECTRIC PLOUGHING AND TRANSPORT

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Part I.—*Electric Ploughing*

Ploughing is one of the most important and heaviest of farm tasks and also the most expensive item on the arable farmer's bill. Opposition to mechanical power for ploughing is often met with in agricultural circles. It is claimed that the introduction of power-driven cultivating machinery, instead of reducing costs, would of necessity increase them, as the keep of the horses would be the same and the mechanical power would only be carrying out the work that the horses would otherwise be doing. There is, however, one fallacy in this argument, for the work of ploughing cannot be extended over a long period and horses can be used for this purpose only during slack periods. For land to be well cultivated the ploughing must be completed as early as possible in the autumn; and again, it often occurs in this country that long wet periods are experienced which delay work on the land, but, when a favourable opportunity presents itself, the farmer who has something quicker than the horse to carry out the work is in a very advantageous position. Further, the modern electric plough can now be adapted for all forms of field work—such as harrowing, rolling, harvesting, etc.

Another argument commonly used is that English fields are too small for this kind of work. This argument, however, is made on the assumption that all electric ploughs are very large sets, capable of covering an enormous area in one day. There are, however, the round-about and tractor types of ploughs, which are quite suitable for small fields—there are many in use to-day in vineyards in the South of France; these vineyards, it must be admitted, are a more difficult proposition than the smallest of fields. A great deal of the author's work has been in the direction of solving the problem of the ideal type of ploughing equipment for the small farmer of individualistic ideas.

It is doubtful whether the operation of ploughing, as at present practised, is really an essential part of tillage, and in this respect it is interesting to note the rapid progress made by the rotary cultivator during the past few years; these machines lend themselves extremely well to an electric drive. The flexible cable passes from

a small mast on the machine through a pulley at the top of a pole fixed at the side of a field, it then hangs in a loop, the end of the loop passing to the mains being fixed to the top of the pole. In the loop there is a pulley carrying a weight, so that the cable is automatically paid out or drawn back at a constant tension, thus preventing it from being accidentally run over.

The 10 h.p. size can deal with an area of from 0·2 to 0·5 of an acre per hour, at a depth of from 4 to 10 in., travelling at a normal speed of 1½ miles per hour.

The 30 h.p. size can deal with an area of 0·5 to 1·5 acres per hour, working to a depth of 14 in.

There are a number of different systems of electric ploughing in operation to-day, though they practically all fall into one of two classes—viz. tractors or rope haulages. The capacity of the larger ploughs is enormous, many ploughing up to 30 acres in one day.

These sets are equipped with either 80, 100, 125 or 150 h.p., 5000 volt, three-phase, slip-ring induction motors, many of which are capable of a momentary overload of 60 per cent. The general design is based on British steam-plough experience, hence only the electrical features are really new. The main disadvantage of this equipment is the very great weight of the haulage sets, which is sometimes as much as 14 tons for each winder, thus large headlands are required. Many ploughs of this type are to be seen in France and Germany, and also in Russia. The method of operation is essentially the same as with the familiar steam-ploughing tackle. Two portable electric-motor haulages are placed, one at each side of the field, each haulage having a steel-rope drum, driven by counter-shafting through the electric motor. The average speed of the steel cable is about 1·66 yards per second, though it is possible to reduce the speed to 1·1 yards per second. With this equipment it is claimed it is possible to plough 30 acres per day, with a furrow depth of 9½ to 12 in. The power consumption per acre on heavy clay soil of average moisture content is about 15 units (kw.h.), while the speed of ploughing is 3⅓ miles per hour.

The majority of double-rope system haulages are similar in design, though many are equipped with auxiliary petrol engines of about 50 h.p. to enable the haulage to move from field to field and from farm to farm, while in others the familiar anchor-wagon device is used.

Continental manufacturers have realized that more attention must be paid to the need of the individual farmer, and have designed sets with this purpose in view.

The Estrade equipment has a number of novel features. The haulage cable passes through a pulley at the end of a pivot arm, whose movement is assisted by a series of oil dashpots. The resultant of the pull and the weight of the haulage always passes

through the line joining the points of contact of the soil and the two inside wheels. These wheels are fitted with flanges, which, with the rims, enclose a prism of earth. In this way great stability is obtained, for, instead of depending on the friction of the iron arms on the earth surface, the much greater friction of this compressed prism of earth on that lying beneath is utilized. The manufacturers claim that this type of haulage gear can provide a pull of three times the weight of the set.

In another new machine, ramps, or inclined runners, are provided upon each haulage set, and when the plough reaches the end of its journey it mounts up on the haulage set, ready for transfer into position for the next set of furrows. Thus, headlands are reduced to a minimum and manœuvring is greatly facilitated.

Electric Tractor Ploughs.—One of the main problems is the method of dealing with the flexible cable connecting the tractor to the supply point. The best principle evolved so far is to mount the feed cable-reel on the tractor itself. In this way the cable is paid out and laid to rest on the soil instead of being dragged after the tractor, while on the return journey it is picked up and wound on to the drum. Various devices are used to ensure that the cable-reel winds and unwinds at the correct speed.

In Italy the ingenious method of attaching the cable to a small balloon (lifting power about 100 lb.), and thus raising it out of the way, has been employed.

Electric tractors fitted with a tramcar-type collecting trolley or bowl, picking up the current from a bare overhead conductor, have not proved satisfactory on account of the trouble in designing supports so as to maintain sufficient tension on the conductor and at the same time facilitate progressive movement at the end of each furrow.

Tractor ploughs are generally fitted with electric motors of from 20 to 30 h.p., and when equipped with three-share ploughs will plough, on an average, 6 acres per day to a depth of 8 in., the current consumption being about 28 units (kw.h.) per acre.

On the author's farm a 12 h.p. modified roundabout electric plough is employed.

The author considers that the double-winder rope system, with petrol engine for field transport, is the most satisfactory for large contractors working over large areas. The *ideal* plough for the farm of 200 acres and upwards has yet to make its appearance. The author suggests that it should be designed with a half-creeper track. The flexible cable should be raised above the ground, with automatic winding and an automatic-feeder cable, similar in design to that employed on the M'Dowall plough. A storage battery should be provided for moving the equipment from field to field, and when not in use on the land or within reach of overhead lines.

The main motor should be of about 25 h.p., while an additional winding motor of about 2 h.p., with an automatic hysteresis control, should be incorporated for operating the cable-drum. A mast should be fitted on the tractor to support the cable so that it hangs free in the air for a distance of about 30 to 40 yards. A plough should be mounted at both ends of the tractor so as to obviate the necessity of turning at the end of each set of furrows. A tractor of this type would plough from 40 to 60 acres from a single contact in the middle of the field. This tractor could also be used for such work as cultivating, harrowing, harvesting, rolling, seed-drilling, etc.

While it is not possible to give exact figures as to the cost of electric-ploughing, since so much depends upon special circumstances in each area, yet the author has calculated the cost of operating some of the machines from figures given by manufacturers and users. On the double-rope system with two haulages, the cost works out at 5s. 7½d. per acre, while the figure for electric tractors is 5s. 1d. per acre. These figures do not, of course, include overhead expenses, but include depreciation, interest, cost of cable, repairs, labour, and electric power at 1d. per unit, the depth of ploughing being from 6 to 8 in. When allowance is made for overhead charges these figures still compare favourably with the contract prices quoted for all other forms of ploughing. Another way of dealing with the cost is to mention that the consumption of electric current for ploughing varies from 15 to 22 units (kw.h.) per acre—a comparatively small sum at 1d. per unit, the usual charge.

There is, of course, still room for improvement in the design of electric ploughs, but it is rather refinement and evolution that is needed, coupled, of course, with the provision of an adequate distribution system to supply the large amount of electric power required.

For the supply of electricity to rural areas the usual type of overhead, three-phase transmission line will no doubt be used, and the only special feature introduced for field work is the method of connecting the high-tension lines to the portable transformer wagon. For temporary tappings it is often done by means of special hooks, having insulated handles and cable connected to the transformer cabin, though a better way is by means of permanent "fool-proof" pole contacts, of which special types already exist for pressures up to 10,000 volts. These are very easily operated from the ground by a long rod, and remove any possibility of wear and damage to the main transmission line.

PART II.—*Electric Transport*

An ample supply of power, which will be necessary for ploughing, will bring in its train many other electro-mechanical aids to the

farmer, and chief among these will be comparatively simple transport equipment which will both expedite and facilitate the work on the farm, thereby reducing the amount of labour employed per unit of work performed.

Handling Crops.—A large proportion of the cost of hay and corn is accounted for by the high labour costs involved in handling the material both in the field and the buildings. A useful method of unloading the crops at the barns is to utilize specially prepared slings or automatic grab forks, in conjunction with an obvious system of ropes or nets, placed in the wagon before loading. The whole operation of unloading can then be performed by one man.

The method most frequently employed on farms on the Continent for hoisting these loads is a modified form of the Temperley transporter system, operated by an electrically driven hoisting gear provided with two hoisting drums and sets of brakes. The gear is conveniently located near the unloading point, thus giving complete control to the men in charge. When the load is hoisted to the top of the barn the pulleys jam, and the load can be traversed in either direction. The whole arrangement is of a very cheap and simple design, and can be operated by a 3-5 h.p. motor.

Transport equipment can also be used profitably at thrashing time—for instance, electrically driven chain-conveyers should be employed to transport the sheaves from the rick or barns to the thrashing-machine, with an automatic device incorporated on the thrashing-machine for cutting the bands on the sheaves and separating each sheaf before delivering it on to the drum. The thrashing-machine could then be permanently mounted on foundations about 4 ft. above floor-level. The installation of a permanent thrashing-machine would make it possible to deal with straw in the following ways: the straw could be (1) baled on leaving the thrasher, (2) passed through a sheaf binder, (3) blown to a straw-yard through a tube, or (4) transported by an inclined elevator. With methods 1, 2 and 4 the straw should be delivered on to a horizontal conveyor, so that at convenient intervals trap-doors can be placed in the run-way, which permit of the delivery of the straw at any desired point. When method 3 is adopted the delivery tube can be as long as 200 yards. It is usual to make up the length with 10 ft. lengths of light galvanized piping. At the end of the last tube an arrestor is fitted so as to collect the straw neatly at the desired point. For driving the grain a distance of 50 yards a 5 h.p. motor-driven fan is required, while an 8 h.p. motor-driven fan will double the distance, and a 10 h.p. size will carry it 200 yards. Where fans of efficient design are used, and attention is paid to the form of ejecting device, even smaller motors can be employed. The capital cost of these conveyors is not high, as they are of very simple design.

The grain can be moved by either "Jacob's ladders" or special

worm-conveyers, delivering it on a horizontal or inclined belt-type conveyor direct to the granary.

With mechanical assistance of this nature one or two men only are needed at the thrasher, while other two pitch the sheaves on to the conveyor.

Central Manuring Plants.—A system of manuring market-gardens by means of stand pipes in the orchards has been carried out for quite a number of years on many Continental farms, especially those in Switzerland. The stand pipes are connected to a manure tank adjoining the main cow byres by means of underground pipes. The urine from the cowsheds flows directly into the tank, and when the plant is about to be used, old rotted manure is thrown into the tank and water added, and the whole contents agitated by means of revolving arms or by circulation through centrifugal pumps.

The question of the supply of electric current for transport purposes and for electro-mechanical appliances for work in the field and in the farm-buildings is relatively simple, if farming is carried on on modern lines, since the power demand would be so great that electricity-supply undertakings would be anxious to cultivate the rural load and would therefore be only too pleased to provide the necessary distribution system.

Recently the writer, in conjunction with Dr A. Ekstroem (the well-known Swedish authority on rural electrification), has prepared a scheme for completely electrifying the whole of Lincolnshire—which is typically an agricultural county. If the scheme can be carried through, rates as low as ½d. per unit will be offered for purposes where the current is used for long periods—such as thermal storage, electric cookers and water heaters. It is hoped to bring a supply of electricity to over 75 per cent. of the inhabitants of the county within six years. In each of the above-mentioned areas a number of typical farms will be completely electrified (including electric ploughs) in the reasonable manner that the farmers would do themselves if they had had many years of experience of the use of electricity, and also knew what farmers in other countries were doing.

THE DISCUSSION

SIR MERRICK BURRELL, in opening the proceedings, said that the purpose of these meetings was to bring together farmers, representatives of industries connected with agriculture, and agricultural scientists for the discussion of specific problems in agriculture. The present Conference was the sixth of the series, which had already dealt with lucerne, fodder crops, sugar-beet, green manuring, and the art of cultivation.

The subject chosen—"Power for Cultivation and Haulage on the Farm"—was beyond question of wide importance at the present time: how far could mechanical power aid the farmer, what form of power was best, and to what extent would it aid, or replace, traditional horse-power operations? His personal opinion was that the horse would continue to hold its own, although mechanical power would prove a very useful aid. He thought that the bulk of the discussion would centre around the tractor, but he asked the audience not to forget the long and honourable record of steam-power, and the claims of electric-power, in which large developments might come in the near future.

Mr W. C. DAMPIER-WHETHAM, in opening the discussion, said that his own experience was mainly on grass-land farms. Horses were cheap to buy, depreciation was small, a team could be split and distributed to different pieces of work—and they were better for small fields. The small development in power in agriculture as compared with other industries is due to the following reasons: (1) industries were localized in factories, whereas agriculture had a diffuse and spasmodic requirement; (2) the farmer's main source of power was the sun, whose energy was utilized by the growing crops, and all other forms of power were subsidiary to this. The development of electric-power was held up in England by the high cost of overhead lines, due to stringent safety requirements. They cost £500 per mile against £200 on the Continent. The amount of power needed per acre was small, but over the whole rural area the load would be economic.

Mr H. DECK (Ransome, Sims & Jefferies) considered that the use of electricity for barn machinery was its most likely outlet. For cultivation and haulage work permanent and movable cables and heavy batteries would be highly inconvenient He thought there would be little immediate change, except in the direction of more economical design, either in the tractor or the implements designed for use with it. Nevertheless there were great possibilities

in deeper ploughing and cultivating. He stressed the importance of speed in all farming operations in our uncertain climate.

Mr Bosanquet of Alnwick (delegate of the Northumberland N.F.U. to the Conference) said that as a practical farmer he supported all that Mr Porter had said. He farmed 1800 acres of light hilly land, mostly reclaimed from moorland within the last one hundred and fifty years. At first tractors were unsatisfactory because buried boulders broke the tackle, but they were excellent for thrashing. He used motors exclusively for haulage, except for carrying rations to the farm-buildings and transporting women workers between the fields and their homes each day, for which light horsed carts were used. This practice has been found so advantageous to the farm work, and is so much appreciated by the workers, that the horse will shortly be replaced by a light motor-lorry, which would also be used for ordinary transport.

Mr J. R. Bond (County Organizer for Derby) thought that the imported-meat trade was largely responsible for the present depression in agriculture, and believed that laying down land to grass could not help. The present difficulties largely arose because of our traditional practice of keeping animals partly to supply manure.

Steam cultivation was too costly. There had been little improvement in engine design since 1850. The engine need not be heavy, and in any case the distribution of weight over the present form did not correspond with the point at which the pull was experienced. Very little had been said about the destruction and killing of weeds during cultivation operations. It seemed as if half of a farmer's life was spent in getting a tilth, whereas it was his experience that more than half of a farmer's life was spent in destroying weeds. He thought that if an efficient machine for this purpose could be devised the time of cultivation work could be greatly reduced.

Mr Black (President, Suffolk N.F.U.) stated that his experience was gained on heavy land in Suffolk, where he could not work his horses for 260 days a year as Mr Porter did. He found the tractor essential to get through the necessary work in time. On large farms it was better to have both heavy and light tractors and lorries rather than general-purpose types. He supported conveyor distribution for produce in the granary.

Mr Van Dijk (Messrs MacLaren's engineer for export trade) said he had come over from the Continent especially for this Conference. On sugar and tobacco soils in Sumatra, where the

soil resistance was very high, he had, after ten years' work, reduced the plough draught by 50 per cent. Had he had the advantage of the Rothamsted studies on soil resistance he could have solved the problem much earlier. The vital question to-day was to reduce tractor costs. This implied a reduction in the number of moving parts in the engine, and the use of crude oil—the Diesel engine was the solution. It was now in use successfully for cable tackle, and smaller tractor types were also in use.

Mr Hugh Young dealt with his experience as a farmer on hilly land at High Wycombe. He stressed the necessity in tractor design for keeping the weight as near the ground as possible and well distributed over a large base. The front wheels of one of his tractors tended to be pulled off the ground when travelling uphill, while another, when working across the hill, tended to topple over sideways.

The purchase between the tractor wheel and the land was the weakest point in present-day design; a four-wheel drive or track-laying type would be better: his three-wheel drive tractor hauled a binder last summer on land so greasy that the two-wheel drive tractor could not manœuvre itself with no load at all behind it.

He strongly urged the desirability of an efficient two-furrow one-way plough for the tractor: no horse plough was needed to open and close the furrows between the lands; no time was spent in driving along the headland between lands, which, for an acre with 200-yard furrows, meant some 380 yards extra travel; the passages over the same piece of headland were three against eighteen with the fixed plough. He invariably used one-way ploughs with horses, and was surprised at the little use made of them in England (except in the anti-balance form in the south-west counties), in view of their great popularity on the Continent. Finally, in his hilly land the tractor was worth its cost for binder work alone.

Major C. E. Bentall (Heybridge Works, Maldon) raised the question of the performance of implements rigidly attached to the tractor. If the essential feature of such an implement was that the wheel of the tractor took the place of the land wheel, it would result in uneven work on uneven land. This seemed an argument against a simple rigid attachment between tractor and implement. With the existing types, the hitch was flexible, thus allowing the plough to follow the contour of the land and maintain an even depth of furrow.

He drew attention to the value of the tractor for broadsharing. This implement was formerly very popular, and did undeniably

valuable work, particularly in stubble cleaning, but its use had been largely discontinued, mainly for the reason that it was considered to overtax horses.

Mr F. H. Johnson (Bull Motors, Ipswich) considered that electric power would be economically used for cultivation only if a single engine were used, the implement being pulled backwards and forwards between this and an adjustable anchor truck, by means of a double haulage rope. This method would halve the number of permanent supply cables needed on the farm and would eliminate the necessity for any flexible conductor winding and unwinding with the movement of the implement—an arrangement that is cumbrous at the best.

Although the above scheme is the most practicable so far as distribution is concerned—which is the governing factor—there is the great disadvantage that the electric tractor and anchor truck must of necessity be hauled to their work by internal-combustion or steam tractors, and the only way that this can be eliminated is to fit the electric tractor itself with an engine, or heavy and expensive batteries, which will enable it to travel by road when disconnected from the distributing wires. The latter introduces complications which would be highly unsatisfactory in the hands of ordinary agricultural labour, and would certainly be very difficult and expensive to install and operate where the supply is alternating current, as it would be in almost every case of rural electrification. For the larger ploughing equipments the question of petrol-electric operation is well worth consideration, as by this method the control of the tackle could be simplified enormously. The whole equipment could be handled by means of a simple drum-type controller, similar to that used on tramcars. The capital cost of the tackle compared with steam gear would be reduced, and the depreciation would also be less. There would be a considerable saving in labour, since no supplies of boiler-feed water and coal would be needed. The petrol-electric system could be made perfectly reliable; the reliability of the electrical portions is at least equal to that of the petrol engine, and, with properly designed machinery, the depreciation on the electrical portion is almost negligible. One advantage of the petrol-electric system is that it would give a very wide range of hauling speeds. It could very easily be so arranged that the maximum tractive effort for which the equipment is designed was developed at any speed from standstill to the normal full speed, corresponding to the maximum output of the engine driving the dynamo. The same plant could also be made capable of developing half the maximum tractive effort for which it was designed, at a speed as high as twice the normal hauling speed if necessary. This would enable a great variety of work to be handled, and on the

lighter work would enable a great economy in time to be effected, provided the maximum speed available could be utilized effectively.

Therefore, by utilizing the electrical drive, an equipment could be provided which has a very wide range of hauling powers and speeds, and able to utilize the various implements which it is designed to haul, to their full capacity. Provided the electrical engineer is shown what is required, there is no reason why he should not produce plant which will deal in a highly efficient manner with a large variety of haulage and other problems.

Lieut.-Col. F. Garrett, C.B.E. (Leiston Works): To get more men on the land and to pay the higher wages necessary we must introduce, as far as climatic conditions allow, mechanical means into agriculture, and thus increase the output per man. My firm has recently developed a device for reducing the labour of haulage on soft or wet land. The idea applies to all vehicles (even tractors) and enables, for instance, one horse to haul a load off heavy land that formerly taxed two.

I disagree entirely with Mr Bond on the development of steam-power; it has advanced quite as much, by higher pressures, super-heaters, valve-gears and turbine systems, as any other form of power. In haulage, ten-, six- and four-ton load steam vehicles are popular, and beat the internal-combustion engine in cost of running, durability and capacity for overloading and overspeeding; steam-power has still many useful outlets in agriculture.

The two grave obstacles confronting electric-power in agriculture are the absence of cheap and light batteries, and the high capital cost of current distribution systems.

Mr B. G. Shorten (J. & F. Howard, Ltd., Bedford): Steam cultivation on large estates has been successfully proved for many years. The smaller landowners and tenant farmers in many cases employ the service of a contractor owning steam tackle. In this way extensive areas have been kept under cultivation which otherwise would have been found most difficult to deal with.

As agricultural engineers, we deplore the present tendency of so much land being laid down in grass. The time is not far distant when landowners and farmers will find it to their advantage to devote more attention to this question of tillage. The figures plainly show that the importation of foreign meat will increase rather than decrease, and with this undoubted position in view, how can farmers hope to make grass-land pay by producing beef in competition with such an array of foreign competitors?

I do not agree with the suggestion that manufacturers have adhered to the principles of the horse-drawn implements in designing tractor implements. I can assure you this is not so. Most efficient

self-lifting arrangements are now fitted, operated by the driver. It has been suggested that more efficiency could be secured by combining the tractor and, say, two-furrow plough, in one unit, braced together with certain flexible movement. On closer experience problems will be found presenting difficulties—*e.g.* a double-furrow plough closely connected to tractor, negotiating uneven surfaces, is deprived of the necessary vertical and horizontal movements required for dealing with rough and heavy soils, and so far more satisfactory results are produced by independent couplings.

While we believe the demand for tractors is steadily growing, and their usefulness more recognized, it must not be taken as indicating that horse-power is on the verge of collapse. The implement production of my firm is about 85 per cent. horse-drawn as against 15 per cent. tractor-drawn. I believe horse-power will continue to be largely used, more especially by the medium and smaller farmers, and, by reason of the variety of duties performed by them, they will remain first favourites with the majority of farmers. I believe the horse, the tractor and the steam tackle, with their suitable implements, hold an important place in the development of our farming industry, and where well and wisely employed, even under existing conditions, all three can be used with progressive and profitable results.

Mr Harold Drewitt gave some figures for the cost of tractor work on his farm near Chichester. His tractor was bought shortly after the War and was very extravagant in paraffin and oil. His second purchase was made about five and a half years ago, and this tractor, in its working life of three years, ploughed 1615 acres (taking 5 acres of cultivating as equivalent to 1 acre of ploughing); the average cost of operations per acre was:

	s.	d.
Labour, fuel and oil . . .	9	6
Repairs	4	2
Depreciation	4	9
Total	18	5

His third purchase was made two and a half years ago, and has, up to the present time, ploughed the equivalent of 1640 acres at a cost per acre of:

	s.	d.
Labour	2	5
Fuel and Oil	4	4
Repairs	1	9
Depreciation	2	6
Total	11	0

These figures do not include belt and miscellaneous work, which was not sufficient materially to affect them.

The driver, who has driven all three tractors, is an excellent ploughman but not a mechanic—all except the simplest repairs have to be done by a skilled mechanic; during the life of the present tractor there has been only one stoppage due to mechanical breakdown. The most expensive part of breakdowns is not the cost of repair but the delay to the work of cultivation.

When there is great pressure of work in the summer, two drivers work the tractor 18 hours a day, thereby doubling the daily output of work.

Mr G. R. Hunter (Midland Agricultural College) thought that interchangeable wheels or tyres for the tractor were of great importance. A figure of 90 days per year seemed to be the average working time of the tractor on the land, and even this was not reached in wet seasons. Some simply attached system of rubber-tyred rims for road work, and a suitable trailer, would be very useful as a means of increasing the yearly working time, and especially advantageous to those farmers whose holdings were some distance from a railway station or market. It would reduce, or perhaps obviate, the necessity for a motor-lorry; a non-governed tractor, fitted with brakes to comply with regulations, would, however, be needed.

He thought that the horse had well held its own in the discussion, and suggested that not enough stress had been laid on the great advantages of higher speed and power that the tractor afforded. On the College farm this year they had, thanks to tractors, been able to cross every stubble twice; few Midland farmers were in that fortunate position.

While he agreed that certain tractor implements, being adapted from horse-drawn types, did not adequately utilize the power of the tractor, the modern disc-harrow should be excluded. Properly set, it taxed the tractor to its utmost and did better work than the horse implement.

Mr T. Milburn (Principal, Midland Agricultural College): The relative value of horse and tractor work was a matter of expediency rather than of cost. Just as the best horse-ploughing could not equal spade-work, so tractor-ploughing could not equal the best horse-ploughing; nevertheless, poor tractor-ploughing done at the right time may give better results than good horse-ploughing done too late in the season. To discuss their relative merits only on a cost-per-acre basis was beside the point.

He was sceptical about hitching harrows behind the cultivator so as to give the tractor a fuller load; for the best results were

often obtained when there was a period between the respective operations to allow the ground to dry, weeds to be killed, and weed seeds to germinate. The same objective applied to rotary tillage.

Mr H. Currant (Farm Foreman, Rothamsted) spoke of his experience with the Austin tractor on the Rothamsted farm.

It was valuable for the autumn ploughing of clean stubbles, and in harrowing down before the drill, when the ploughed land was dry enough. The tractor was most useful in the cultivations for spring crops and roots. The land could be re-ploughed and tilled quickly, and the extra depth of cultivation needed for roots could be easily obtained without upsetting the horse work. Further, the tractor could deal with any field needing bare fallowing, and plough and cultivate it as many times as it might require. One could not plough fallow land too much in the summer when the land is dry.

For neatness of ploughing on clover, ley or stubble the single-furrow horse-plough beats the tractor, because it is the same plough following round its own work, and it is "held" by the ploughman; the tractor-plough, being pulled along and guided only by the tractor, cannot be expected to turn out work of the same quality.

Rolling the corn with the tractor is not an ideal job; a big acreage can be covered in a day, but the wheel-marks show below the roller and much of the corn on the headland gets over-rolled. But it will deal really well with a rough piece of uncropped land in the spring or summer; working in the low gear it will take a heavy set of harrows fastened behind the roller if desired. The tractor was unsuitable for drilling, ridging or bouting some of the lighter harrowing, rolling and, if he might use the term, "horse-hoeing": neither could one divide up the horse-power of the engine and use it for so many carts in times like haytime and harvest.

In conclusion he invited the tractor-plough makers to fit a more efficient skim coulter, as one of the chief difficulties in tractor-ploughing was to bury the rubbish. He also urged tractor manufacturers to fit some plugs that will not persist in oiling up, and to provide a more comfortable seat for the driver.

Mr G. A. Barber (Messrs. J. & H. McLaren, Ltd., Leeds): The various papers read to-day emphasize the need for greater economy on the farm. As a means to this end I would advise the more extensive use of machinery. The most up-to-date implements and power units, embodying simplicity and low running costs, must be employed. The use of machinery requiring highly skilled labour is neither advisable nor necessary for farm work to-day. A large proportion of the agricultural machinery produced in this country at the present time is sent to foreign countries where only native

labour is available for operation. Mechanical cultivation may be divided into two systems—namely, the Cable system and the Direct system. In the Cable system the steam engine is being replaced by the motor-windlass, in which Diesel Oil Engines are used as the prime mover. This has reduced the working costs tremendously, and, in addition, provided a power unit weighing 7 tons as against 14 to 17 tons in the case of the Steam Cable Engines. Such a tackle can be worked in the field practically all the year round, and its light weight greatly facilitates its movement from field to field. The Diesel engine has the flexibility of the steam engine, and such complications as magnetos and carburettors—the two parts requiring special care and attention—are eliminated. The fuel costs for ploughing 500 acres, double cultivating 500 acres, also harrowing and rolling 1000 acres, amount only to £75 on medium to heavy soil, the depth of work ranging from 6 in. to 12 in. A variety of implements can be worked with this system, and a series of change-gears permit the implement to be operated at the desired speed, in accordance with the views expressed by Dr Keen.

In the direct traction system, too, the steam engine has been superseded by the internal-combustion engine, the very latest developments being the introduction of the Diesel Engine Direct Tractor. The fuel costs per acre with this tractor are under 1s. when working in average soil—a great advance in economy when compared with the petrol tractor. Simplicity here, again, is the keynote, and as the whole of the mechanism is enclosed—a point stressed by Mr Burford—a long life is assured.

The work I have seen carried out with rotary tillers both in this country and abroad does not lead me to believe that this class of implement will be extensively adopted in this country.

Mr J. E. Newman (Institute of Agricultural Engineering, Oxford): The objections raised by the ordinary farmer to the tractors are usually—(1) difficulty of maintenance, and (2) padding the ground. With regard to maintenance, the most modern tractors have reached a high degree of reliability and with ordinary care should give little trouble. Much of the trouble experienced in the past has been due to faulty design, and even now there is room for improvement. Farm tractors, under working conditions on many farms, cannot be garaged every night without serious loss of working time, and tractor designers should recognize the fact.

A good deal has been said about the non-mechanical nature of the ordinary farm hand, but there is no reason why agriculturists should include a lower proportion of mechanically minded folk than the rest of the community.

The farm of to-day, apart from tractors, has a lot of machinery. Consider the binder—one of the most complicated bits of machinery

there is. On the mechanical farm of the future, men with a mechanical bent will be as necessary as those with a love and eye for animals on a present-day stock-raising farm.

These objections to the use of tractors apart, the gravest objection most farmers have to it is that it will pad the ground. Our climate and the nature of our soil make this objection a real one, though the ill-effects are often exaggerated. Padding, or compression of the soil, is caused more by the tractive force of the machine than by its dead weight, and it is bound up with the shape of the lugs or strakes and the size of the wheels. Caterpillar tracks have the great defect of heavy cost and of excessive wear. It seems doubtful if these are not inherent in the design, and it is possible that some form of skeleton wheel will be the eventual solution of the difficulty. The Institute of Agricultural Engineering has had the Dawe Wave Wheel under observation for some time, on tractors of varying weights. When these wheels are fitted to a light tractor—such as a Fordson—the wheel-tracks can be harrowed out, and they have the great advantage that when the tractor is being used for general haulage on the farm it can move off soft ground on to a hard farm road, or go through a muddy gateway without slipping.

If further experience bears out our present opinion, they, or some development of the principle, will greatly increase the all-round utility of the tractor. It is this which needs to be increased; the number of hours which many tractors work is far too small, and it is chiefly by increasing the number of jobs which the tractor does that this can be altered. Of course, not only are our implements designed for the horse, but to a large extent farming practice is based on the use of the horses as its main source of power.

Now that a more economical source of the power is available, some of our practices might be altered with advantage. Such alterations will, however, come gradually, as the result of experience. I might mention as an example of greater experience and confidence, that tractors are now used in the hay-field to pull hay loaders. This is now common, but six years ago was hardly heard of. The tractor does this job better than horses, it pulls more steadily, particularly with a big load, and the wheels straddle the window, whereas horses walk on it.

I agree with Mr Bond about steam cultivation. The great weight of the present sets is at the bottom of most of the objections to their use: and that weight is not necessary to prevent slipping. Witness the ability of the M'Laren Diesel Motor Cable sets to work, and their success. At the same time the cable system has probably had its day in this country, and no improvements can be expected to sensibly increase its sphere of usefulness.

As Mr Black said, it is unlikely that one type of general-purpose tractor can do all the work of all farms. Possibly the evolution of the tractor will be in two ways, one being in the direction of a stronger machine capable of easily ploughing three or four furrows in strong land, and used for cultivation work proper and the heavier belt-work—as thrashing—the other being in the direction of a light machine, capable of doing the work of a four-horse team and used for harvesting and drilling and the lighter work generally. Such machines are being evolved, and are necessary if horses are ever to be replaced to any considerable extent by tractors.

Mr J. W. Collis (Tractor Traders, Ltd.): Cost data, while of very great value, is most difficult to compile to apply to all conditions. In making comparisons as between horse and tractor work I do not think sufficient stress is laid on the many jobs the general-purpose tractor can do. I submit that with the "caterpillar" or track-laying type of tractor there is hardly any work on the farm it is not capable of doing.

On the question of electrical power, it is significant that in countries where it is so easily obtainable from natural sources—*e.g.* the "Niagara Peninsula"—it has not been applied to farm work on a far-reaching scale.

Hardly enough stress was laid on the necessity of more draw-bar horse-power in the tractor and the advantage of securing deeper tillage so essential for the cultivation of sugar-beet and other root crops. Direct traction is much cheaper than steam tackle by stationary engines, but the necessary power must be available at the draw-bar without track slippage to do the work. I agree with Mr Deck that to take advantage of the speed and superior draw-bar horse-power of the better type of tractor, and to produce a satisfactory implement to use with it, requires the closest possible co-operation on the part of the tractor manufacturer, the agricultural-implement manufacturer and the agricultural expert.

Captain E. H. Gregory (Rothamsted) pointed out that no comparison was made between roads necessary for lorry work and horse work.

Both the farm wagon and cart are capable of standing the strain of bad roads, and at the same time carrying heavy loads. The lock of the wheels of the modern farm wagon allows it to turn in its own length. The horse is able to get on to other ground leaving the weight of the wagon on the road. An attempt to turn a lorry on a very wet day in a small track will, without doubt, lead to the bogging of the lorry directly it gets on to soft ground. Again, the condition of these tracks is generally so bad that the continued use of a heavily laden lorry on them would not only

make them worse, but would most decidedly shorten the life of the lorry. Lorries in use on such tracks are either of the 7 cwt. or the 1 ton type, and even these have difficulty in negotiating the roads in bad weather.

The question of repairing the roads so that they may be fit for use with motor traffic is one which would involve a great deal of money. In many cases the farmer is bound by his lease to keep his roads in repair. A few cart loads of stones are put down at most irregular intervals in order to fill up the holes, for as long as a farm cart drawn by a horse can proceed along the road, it is in a state of good repair. The main roads throughout the country are gradually being altered in order to stand the extra heavy wear they receive on account of the increase in lorry traffic. It therefore follows that, if this increase is to spread to the farm, the same change, even if on a smaller scale, will have to take place on rural roads, and the question is, who is going to pay for it?

Mr J. M. BANNERMAN (Agricultural Economics Research Institute, Oxford) stated he had undertaken, under the auspices of his Institute, an examination of the economy of power on the farm, and the resultant effect on the efficiency and standard of living of the farm labourer. The economic evidence put forward, while representing adequately individual examples of actual fact, only serves to draw attention to the necessity of a much wider survey. Issues of deeper significance are also involved. For example, stress is laid in these times on the trend of the efficient agricultural labourer towards the town, and it is one of the crucial questions whether or not this efflux of the best rural worker could be stemmed in proportionate degree to the introduction of machinery. The ideal of obtaining an approximation of rural to urban conditions, both of work and standard of living, is a strong justification for Mr Matthews' advocacy of electrical power on the farm. The recent Electricity Bill should make the availability of this form of power more universally possible.

All the factors that contribute to the efficiency and contentment of the rural worker are of far-reaching importance, and discussions concerning improvements, mechanical and otherwise, on the farm would, I think, be ultimately of greater use were the social and economic point of view kept well to the fore.

Sir JOHN RUSSELL, in summarizing the discussion, said that four main points arose: (1) The need of elasticity in the source of power: in this direction horses were superior; (2) The necessity for getting the utmost out of the source of power: at present horses still retain an advantage here because of the traditional love of the farmer for them, which showed itself in the attention given

to keep the horses fit; but this was a decreasing advantage because with the coming of the bicycle, and later the motor-cycle, into rural life, a mechanical turn of mind was growing up in the country-side; (3) The close adaptation of the implement to the source of power: here, again, the advantage of the horse was declining and improvements in power-drawn implements were constantly being made; this work necessitated the co-operation of the implement manufacturer, the engine manufacturer and the soil investigator; (4) The necessity for keeping up the speed of work so as to be well ahead in all operations: here the tractor was definitely superior, especially as it could do the extra emergency work, which was beyond the capacity of horses.

GENERAL SUMMARY OF PAPERS AND DISCUSSION

By B. A. KEEN, D.Sc., F.Inst.P.

(1) Six forms of power are in use, to varying degrees, on the present-day farm: horses, and engines whose motive power is (*a*) steam, (*b*) gas, (*c*) petrol or paraffin, (*d*) low-grade fuel, (*e*) electricity.

(2) None of the mechanical forms of power is likely to replace the horse in the near future. The horse is very adaptable; a team can be split up and distributed to different kinds of work. The main functions of mechanical power are to provide a reserve of power for heavy and urgent work in cultivations and harvest, and to release horses for haulage work. The general characteristics of each form of power are discussed in the following paragraphs.

(3) *Steam.*—This is the most flexible form of power. Increased load does not "stall" the engine, but merely reduces its speed. It has long been established for deep and rapid ploughings and cultivations, in the familiar cable outfits. The work is done almost entirely by contract, few farmers having enough large areas to justify owning a set. Some difference of opinion exists as to whether the heavy weight of the engines is really necessary; and haulage of water and coal to the engines, and the time spent in getting up steam, are regarded by the farmer as disadvantageous. The development of steam wagons for general road haulage has not yet spread to agriculture.

(4) *Gas.*—Its use is confined to stationary engines, for driving barn machinery, etc. Very few gas engines are in use, and their number is decreasing.

(5) *Petrol or Paraffin.*—Engines of this type constitute by far the greatest number in use on the farm, and their number is constantly increasing, both in the form of stationary engines and tractors. Modern designs are much more economical of fuel and oil than those introduced just after the War, and stoppages due to mechanical defects have been largely overcome. Stationary engines are used for barn machinery, although the tractor is commonly employed for the heavier belt-work, in addition to its use in hauling binders and cultivation implements. Its use for road haulage has hardly begun as yet.

(6) *Low-grade Fuel.*—Heavy oils and low-grade fuel can be successfully utilized in the Diesel type of engine with the double reduction of fuel costs and depreciation, because of the simpler

form of engine, fewer moving parts, and lower temperature of ignition. The use of Diesel-type engines for cable-tackle sets is now an accomplished fact, and a successful form of light tractor also is said to be in use.

(7) *Electricity*.—The electric motor is by far the simplest form of prime mover. There are only the two main bearings and the brush-holders requiring occasional attention, and no mechanical aptitude on the part of the worker is necessary. The necessity for a cable that has to be wound and unwound as the implement passes across the field is a drawback for cultivation work, and a grave difficulty is the necessity for a storage battery or petrol engine for independent motive power.

(8) It appears that steam-power will continue in use for heavy cultivation work, but may be seriously challenged by the Diesel engine; on the other hand, the steam wagon may be developed for haulage of farm produce to market. The paraffin or petrol tractor will for some time be the most general form of farm power for belt-work, cultivations, harvest operations, and perhaps road haulage. Electric-power can increase only with a spread of electrification of the rural areas, and the heavy cost of overhead lines, due to stringent safety precautions, is a serious obstacle. Calculations indicate that the total rural load would be economic, while electric light in the homes and in the farm-buildings would add to the comfort of the workers, and improve their efficiency. The petrol-electric system, that aims at combining the advantages of electric drive with the independence from fixed cables of the petrol engine, appears worthy of serious attention.

(9) There is general agreement on the design and specification of the general-purpose tractor—*i.e.* the machine for the average farm, where one only, or at the most two, would be employed. It should be of the light type, weight about 30 cwt., centre of gravity near centre of wheel-base and as low as possible; 22-30 h.p.; revolutions not exceeding 1200 per minute; strong and efficient radiator; gear drive fan and water pump; governed engine; magneto ignition; forced lubrication; strongly designed crank-case; accessibility to all parts needing adjustments; dust-proof ball or roller bearings; gears machine-cut and heat-treated, and of the highest grade material; rear axle of strong design, and front axle sprung and pivoted; two forward speeds and reverse, and efficient brakes on rear wheels for road haulage; fitted with oil filter and air clarifier; adjustable draw-bar, pulley for belt-work, and independent power take-off for direct coupling to machinery; speed and power to drive full-size thrashing machine; facilities for rapid conversion of wheels from farm work to road haulage, and *vice versa*; protection for driver from dust, etc., and a comfortable seat.

(10) For larger farms, especially those on heavy land, the

general-purpose machine is not so suitable as two separate types: one a heavy tractor for three- or four-furrow ploughing, and the second of lighter design for cultivating, belt-work, etc.

(11) The general-purpose tractor is used for about 300-700 hours yearly, as against 1700 hours or more for the horse. The average cost is about 3s. per hour of work; the corresponding figure for the horse is 5¼d. This comparison does not take into account the extra speed and power of the tractor, enabling it to do more work per hour. On a cost-per-acre basis, where these factors are included, the tractor is cheaper than horses for ploughing, but dearer for all other forms of cultivation.

(12) Where the tractor is given a full load, therefore, its cost of operation compares very favourably with horse-power. The present forms of tractor implements—with the possible exception of ploughs—do not give the tractor a full load, and the practice of hauling implements in tandem—*e.g.* two binders, or harrows following cultivators—is not always possible, and certainly not convenient, with present designs.

(13) At present the tractor finds its chief outlet in ploughing after harvest, spring ploughing and cultivations, haulage of binders and driving of thrashers. It is of the utmost value, especially in times of pressure, and even if the cost of operation were much higher than it actually is, it would amply repay this by its ability to get work done at critical times.

(14) The design of tractor-drawn implements, with few exceptions, has not kept pace with the development of the tractor. This is perhaps the chief factor limiting its more extended use on the farm.

(15) There are suggestions from practical men that the tractor plough should be improved: a two-furrow one-way type is advocated, linked on to the rear of the tractor and not hooked on to the drawbar. The linkage would have to be such that a reasonably constant ploughing depth was maintained on uneven land. The ordinary skim-coulter also is said to be unsatisfactory. The disc harrow is said to be very suitable for tractor work. The killing of weeds is a most important object in cultivation operations, and if implements were designed with this aim more specifically in view it is possible that the actual number of operations now considered necessary to produce a tilth could be reduced.

(16) The use of combined tools, of the rotary cultivator type, is now well established for light market-garden soils. For ordinary agriculture they are still in the experimental stage. Since the aim of this machine is to produce seed-bed in one operation, the problems of soil tilth are of special importance. The use of a light machine that, with suitable attachments, could hoe and cultivate between the rows of root crops is a possible development of considerable promise.

(17) The use of the tractor for road haulage of farm produce is, apart from the general question of suitable rural roads, dependent upon (*a*) some simple and rapid attachment for conversion of land wheels to road wheels, or *vice versa*; (*b*) increased speed. Since rubber-shod wheels are practically standard equipment for road vehicles, and since, for land work, a proper grip is essential to prevent slipping and loss of effort, it appears that both rubber blocks, and strakes or spuds, must be provided, in a readily interchangeable form. Although there are some promising designs, they are still in the experimental stage. The track-laying or caterpillar track has not yet found extended favour in this country; neither has the four-wheel drive. The latter is worthy of fresh attention from designers.

Increased speed of work would be of great use for cultivations as well as road haulage. It has been shown that, as far as the soil resistance alone is concerned, the extra draw-bar pull needed increases much more slowly than the speed of work. Although, in addition to this, there would be increased power needed to propel the tractor itself at the higher speed, it appears that the limit of compromise between speed and durability has not yet been reached.

(18) The traditional policy of laying down land to grass in periods of agricultural depression may need revision, in view of the great developments in the imported-meat trade. One alternative would be an intensification, in suitable areas, of arable farming in which special attention would be devoted to vegetable products of a semi-market-garden type, whose culture would call for the extended use of power farming methods.

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