

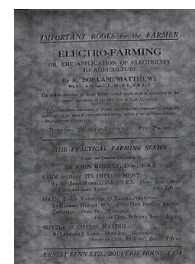
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Power for Cultivation and Haulage on the Farm

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HORSE AND MECHANICAL POWER IN FARM OPERATIONS

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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) <i>Fixed or portable</i> —			
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) <i>Motor tractors</i> —			
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.

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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

<i>Year</i>	<i>Rothamsted</i>	<i>S.E. England</i>	<i>Eastern Counties</i>
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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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.

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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

	<i>Rothamsted</i>	<i>South East</i>	<i>East</i>	<i>South West</i>
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—				
Horse . .	1/6	...	2/7	...
Tractor . .	2/1			
Harvest—				
Horse . .	2/7	2/8, 2/1	...	...
Tractor . .	3/11	3/6, 4/7 $\frac{1}{4}$	4/3 $\frac{1}{2}$	...

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.

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(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

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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

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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